ORCHARD BARK BEETLES AND PIN HOLE BORERS

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., OCTOBER, 1913.

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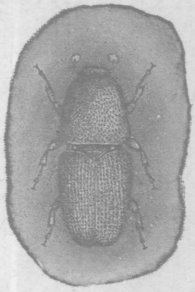

Fruit Bark Beetle

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 264 OCTOBER, 1913

ORCHARD BARK BEETLES AND PIN HOLE BORERS

BY H. A. GOSSARD

SUMMARY OF IMPORTANT CONCLUSIONS

1. Several species of beetles make shot-holes or pin-holes in the trunks and branches of fruit trees. Some of these same insects burrow into young twigs at bases of buds. The holes in the trunk and branches may penetrate into the heartwood, or they may spread out into many channels and ramifications in the cambium or sapwood. The most dangerous species are those which mine in the sapwood, and are, therefore, true bark beetles.

2. Some kinds of trees, such as peach and cherry, exude large quantities of gum through the openings in the bark made by the beetles, and the surface of the bark may become coated over with pints to gallons of gum, depending upon the severity of the attack and the size and vigor of the trees. Again, such trees as apple and pear do not gum at all when attacked.

3. Trees that are in an unhealthful or weakened condition are most apt to be attacked. However, both the Fruit Bark Beetle (*Eccoptogaster rugulosus*) and the Peach Bark Beetle (*Phloeotribus liminaris*), the two most destructive species, burrow into the bark of healthy trees in the fall to feed, or in case of the latter species, to construct hibernation cells, and from these holes gum may exude in great quantity the succeeding season. By repeatedly attacking healthy trees in this manner for two or three successive seasons, the beetles are apt to weaken them to such extent that they are suitable for sustaining larvae, and the eggs are then laid in specially constructed burrows. The larvae, mining the sapwood in all directions, will, if numerous, kill a tree in a very brief period. So long as a tree is able to exude gum plentifully, there is hope for its recovery. The gum exuding into the burrows chokes the passages, rendering them uninhabitable by the beetles or young.

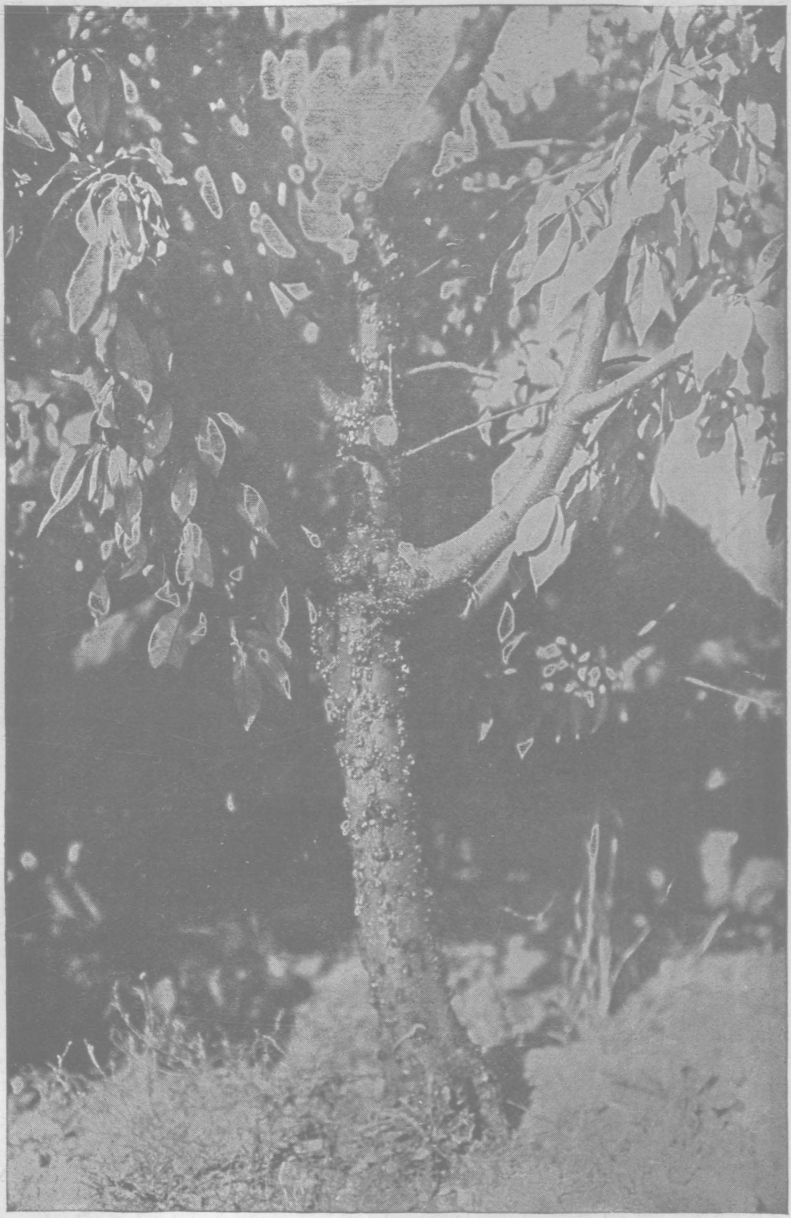


Plate I. Peach tree gumming from attack of Fruit Bark Beetle (*Eccoptogaster rugulosus*).

4. There are two broods per season of the Fruit Bark Beetle (*Eccoptogaster rugulosus*), the adults of the first brood appearing during the latter half of May, and in maximum numbers during the first half of June, the brood being practically over by that time, though a few females linger for a month longer. Eggs are laid in a few days after the appearance of the females and hatch in 3 or 4 days. Each female deposits from 30 to over 100 eggs, with an average of about 75 to 90. The larvae mature in 30 to 36 days after hatching and pupate in the burrows. The pupal period lasts from 7 to 10 days, and the beetles of the second brood commence to appear about the middle of July and continue to issue until late August or early September. Some of the beetles of this brood may linger until late October. The progeny of this brood hibernate as larvae in the bark and develop into the early brood of beetles the next May and June.

5. The Peach Bark Beetle (*Phloeotribus liminaris*) hibernates in the beetle form in special cells in the bark, becoming active in late March and early April. The beetles at once commence excavating burrows in dead or living wood, but use only dead or dying wood for incubation burrows. They commence laying eggs about the 20th of April, and each female will, under normal conditions, deposit from 80 to 160 eggs. These eggs hatch in a few days and the larvae require 25 to 30 days to become grown. The pupal period extends over 4 to 10 days, and the beetles of the summer brood appear about the middle of July, maximum emergence occurring during the latter part of August. Beetles continue to appear irregularly until October. The progeny of this brood of beetles are larvae during the fall months and mature as beetles upon the approach of cold weather, but do not leave their hibernation cells until the following spring.

6. The external opening to the burrows of the two species of bark beetles, *Eccoptogaster rugulosus* and *Phloeotribus liminaris*, may be distinguished from each other by the openings to the burrows of the latter being partly filled or covered over with exuded particles, these being held together by a fine, silken web, which is not true of openings made by the former. The engraving work of the two species is also quite different. The main burrow of *E. rugulosus* extends approximately parallel with the axis of the trunk or branch in which it is made, and the galleries of the young larvae branch out from this at right angles, but because of crowding as the insects increase in size, the galleries commence to slant outward toward the ends of the main burrow, with the result that the engraved area, when completed, is something of an oval. On the other hand, the main burrow of *P. liminaris* is nearly always formed transversely

across the trunk or limb, but is occasionally inclined at an angle of 45 degrees, or less, to the axis of trunk or branch; also a small fork is always formed well toward the inner end of the burrow, commencing where the burrow first touches the sapwood.

7. There are several species of small beetles whose work somewhat resembles that of the two species before mentioned, making small holes through the bark into the heartwood or sapwood, or at the base of the buds into the twigs. However, the methods that are effective for the two most important species will be, in a large measure, successful against all.

8. Probably the most important measure to prevent multiplication of all these beetles is to promptly burn all prunings, dead wood and dying trees.

9. Attacked orchards can be successfully reclaimed from attack by cultivation, by liberal fertilization with barnyard manure and commercial fertilizer, and by whitewashing or spraying with carbolized soapy mixtures. (See page 48.)

10. Treatment should commence in the spring. Prune severely, spray before the leaves appear, and apply a heavy coat of whitewash to the trunks and larger branches in early April. Cultivate and fertilize as soon as the ground is in suitable condition; apply a second coat of whitewash or other repellent in early July and a third about the first of September. Apply thick whitewash with a broom; thin mixture may be applied with a spray pump, but should be repeated until a good coating is secured.

ORCHARD BARK BEETLES

INTRODUCTION

Few, if any, insects can more quickly kill a tree than those small beetles known as bark beetles or quite generally as shot-hole borers. The adult beetles make the small openings, resembling shot holes through the outer bark, either to obtain food or to construct brood chambers in which their young can develop. The larvae of the most destructive species make numerous radiating, sinuous galleries through the growing or sapwood, thus attacking the tree in a vital part. Thus, it may happen that a tree will suddenly wilt and die in midsummer before the owner has noticed that it is in any way diseased; however, such an attack generally indicates a low state of vitality, and weakened trees are certain to be the ones first chosen for destruction. Healthy trees are sometimes attacked, but are rarely or never killed within a brief space of time. The most common species is the Fruit Bark Beetle, *Eccoptogaster rugulosus*, often called the Shot Hole Borer. It attacks nearly all species and varieties of orchard fruits. After this species, the Peach Bark

Borer, *Phloeotribus liminaris*, ranks next in importance in Ohio, and, at its worst, this beetle can do as much damage as the first. A few other nearly related species have somewhat similar habits, being known as Pin Hole Borers, but these are of minor importance and are, therefore, given but brief notice in this publication. These Pin Hole Borers make their burrows in the heartwood, but the external openings through the bark resemble the exit holes of the Shot Hole Beetles, except that they are smaller.

Following the devastation wrought a few years since by San Jose scale upon peach orchards situated along the shore of Lake Erie, came an outbreak of bark beetles, which not only threatened the destruction of all uncared for and diseased trees, but menaced valuable and healthy orchards as well. When this outbreak was first brought to the attention of the Experiment Station, the Department of Entomology was unable, with its slender resources, to handle the matter alone, since the life history under normal outdoor conditions could only be determined by a man stationed in the infested district, and the resources then at our command permitted the employment of only one assistant. Through the kindness of Dr. L. O. Howard and Prof. A. L. Quaintance, of the Bureau of Entomology, U. S. D. A., Mr. H. F. Wilson was employed by the Bureau and stationed in the infested region during the spring, summer and fall of 1908, working under the joint direction of Prof. Quaintance and the writer, the field expenses being borne by the Station. Mr. Wilson made careful life-history studies of the two species of bark beetles at work and also conducted experiments on a considerable scale to determine the best methods of control. The more important facts regarding their life cycles and habits, as set forth in the following pages were determined by him, and have since been confirmed and added to by a number of other observers, particularly by Mr. J. L. King, who has given us the best records and account of the Fruit Bark Beetle or Shot Hole Borer. Mr. Wilson's work upon the Peach Bark Beetle, *Phloeotribus liminaris*, was put into order and published as a bulletin of the Bureau of Entomology, U. S. D. A.,* according to the terms of cooperation agreed upon between the Bureau and the Experiment Station. The following summer (1909) Mr. L. L. Scott, now of the Bureau of Entomology, U. S. D. A., was stationed at the headquarters formerly occupied by Mr. Wilson and carried on, under the exclusive direction of the Experiment Station, the largest remedial tests that have yet been undertaken against these two species. He also accumulated some additional life history data, relating more especially to *Eccoptogaster*

*Bulletin No. 68, Part IX.

rugulosus, and secured some confirmatory records relating to *Phloeotribus liminaris*. His economic conclusions, being based on large tests, and having been confirmed by subsequent experiments and observations through four or five seasons, are adopted as being substantially correct. During the following two seasons, 1910 and 1911, Mr. R. D. Whitmarsh conducted similar experiments, but because of having his headquarters at Wooster and his time being largely claimed by other matters, he was not able to do more than confirm a part of the work of the preceding two years. The past two seasons (1912-1913) Mr. J. L. King has had a laboratory at Gypsum in the Lake District and has devoted his time to investigating a number of the important fruit pests found in this fruit-growing center. Part of his results consist of numerous important records which have been added to the data previously accumulated regarding bark beetles. All photographs and drawings shown in this bulletin and not otherwise accredited were made by Mr. King. Mr. W. H. Goodwin has also contributed to the investigation at different times, having had practical charge for brief periods of the application of the remedies in the field, owing to the sickness or absence of those more immediately responsible for the work. The general planning and outlining of the work has been done by the writer, also much field inspection, and some of the field applications of remedies were made by him.

We are indebted to many residents of the Lake Shore region for substantial aid and cooperation throughout the period of this investigation. Perhaps it is not invidious to make special mention of the courtesies extended and the aid rendered by Mr. W. H. Wright, of Lakeside, and Mr. Wm. Miller, of Gypsum.

THE FRUIT BARK BEETLE

Eccoptogaster rugulosus Ratz.

HISTORY

This insect was first described in 1837 from European specimens and seems to have been first recognized in America in 1878. It was at that time reported to be damaging peach trees in Elmira, N. Y., and its identity was established by referring specimens to the eminent coleopterist, Dr. J. L. Leconte. A few years earlier than this, Dr. C. V. Riley had received the same insect from Williamsport, Maryland, and also from Hillsboro, Missouri, but did not recognize the species. In 1880 it was reported from Fairhaven, New Jersey, and also from Coopersburg, Pa. In 1884 it was reported from Cambridge, Mass. In 1885 and 1886 it was noted as doing considerable damage in North Carolina. It seems to have been established in the west fully as early as in the east. The report of Dr. S. A. Forbes, State Entomologist of Illinois, for the years 1889 and

1890, indicates that it was well scattered over the southern part of that state at that time and must have been present several years before being discovered. In 1888 Prof. J. M. Stedman gave notice to it in Bulletin 44 of the Missouri Agricultural Experiment Station and stated that it was found as far west as Kansas. Prof. V. H. Lowe contributed some observations on the species in Bulletin 180 of the N. Y. State Agricultural Experiment Station. He reported it as having been quite serious in the vicinity of Geneva, and also in Monroe and Niagara counties, N. Y., during the summer of 1900. At the present writing it seems to be distributed over practically all of the territory east of the Mississippi River and spotted over several states west of this stream. The following excerpts from letters of Entomologists residing in these western states doubtless give a fairly accurate record of its present distribution and importance:

Texas: "Quite generally distributed in this state. It occurs in all of our fruit-growing sections in the central and eastern portion of the state, often in very large numbers. It has been abundant in a good many sections for the past ten years."—Professor Wilmon Newell.

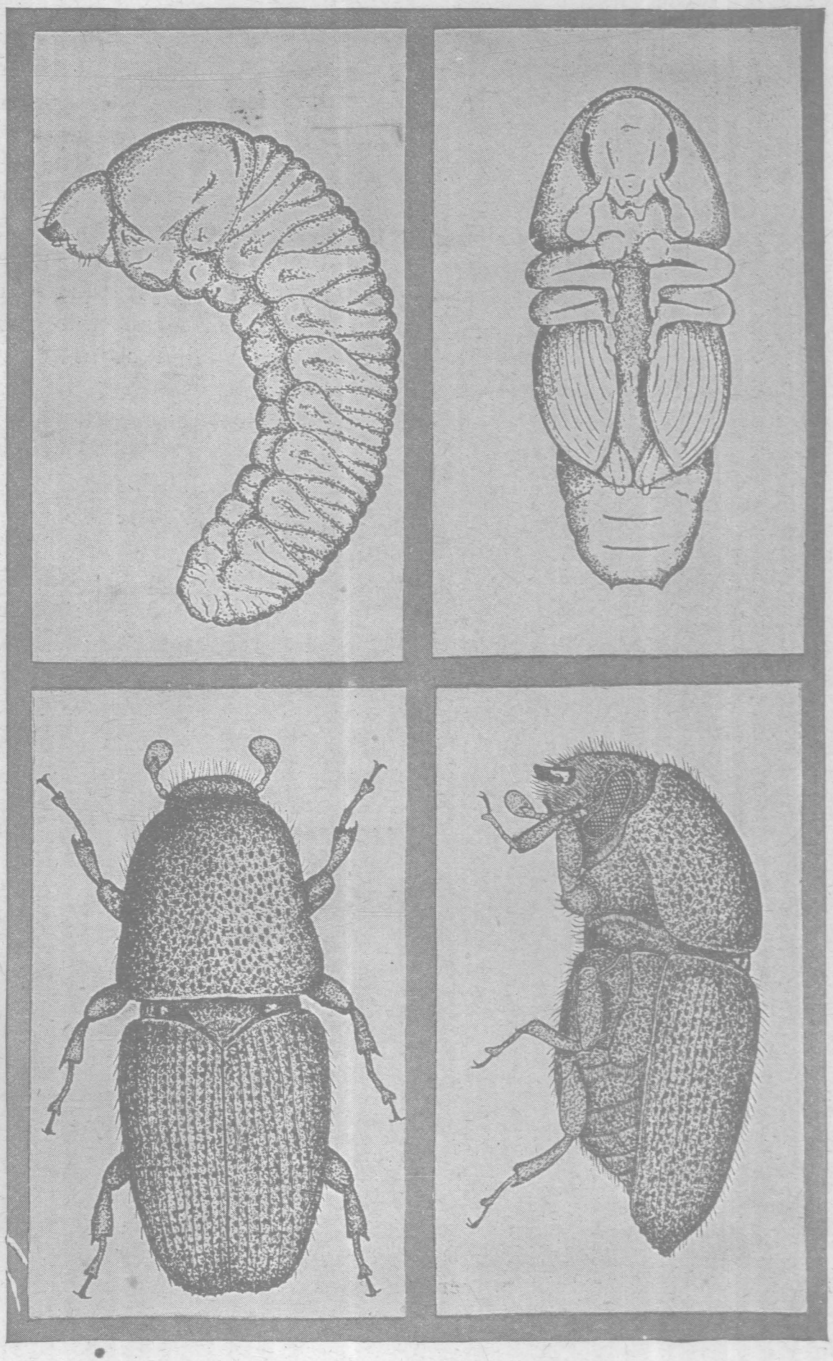
Oklahoma: "*Eccoptogaster rugulosus* not reported before 1897 in this state; at present, it is present in about thirty counties. This beetle does a great deal of damage in this state."—Professor C. E. Sanborn.

Kansas: "First mention that we can find of it is in the Trans. Kan. State Hort. Soc., 1898, by E. A. Popenoe, who states that his first notice of it was in 1897, during nursery inspection. It is now quite common in this state and is quite generally distributed, but is not considered a very serious pest, as the damage is not very heavy."—Professor S. J. Hunter.

"It occurs throughout Kansas wherever there are enough of its food plants growing to support it."—Professor T. J. Headlee.

Nebraska: "This insect has been present in Nebraska for at least six or seven years. While not very abundant, it occurs occasionally in the southeastern counties and, in one or two instances, was found to have completely destroyed several small fruit trees."—Professor Lawrence Brunner.

Iowa: "Occurs in Iowa, occasionally clear to the western border of the state. I have scattered localities across the entire state. It has, in a few instances, done considerable damage locally, although it does not yet seem to be universally enough distributed so that the total harm is very great. I have no record of it, preceding my first finding of it in 1901."—Professor H. E. Summers.



—*J. L. King*

Plate II. Full grown larva, pupa, and dorsal and side view of beetle of *Eccoptogaster rugulosus*, greatly enlarged.

Minnesota. We find in our collection no specimens of the Fruit Bark Beetle from Minnesota, nor have we received any complaint of this insect. Dr Lugger, in his Fifth Report, 1899, refers to it as "Not yet found in Minnesota, but uncomfortably near it, etc."—Professor F L. Washburn.

Arizona: "I have not, during my three years of residence, discovered any evidence whatever of any species of fruit bark beetles here."—Dr. A. W. Morrill

Colorado: "This insect occurs in the orchards of the Arkansas Valley below Pueblo, but I have never known of it in any other portion of the state. It has not been a serious pest in the Arkansas Valley to the present time."—Professor C. P. Gillette.

Utah: "I have seen no indications of the presence of *Eccoptogaster rugulosus* in this state. I have kept a rather close outlook for the insect."—Professor E. G. Titus.

Montana: "I do not believe this insect occurs in Montana. We have spent much time in the orchards in all parts of the state and have never taken any specimens."—Professor R. H. Cooley.

California: "Personally, I do not know of the occurrence of this beetle in California. However, in order to get reliable data, I have written to Professor H. C. Fall and Professor C. W. Woodworth. Both of these gentlemen state that this beetle does not exist in California."—E. O. Essig, Sec'y State Com. Hort.

Oregon: "*Eccoptogaster rugulosus* is not found in Oregon." – H. F. Wilson, Assist. Entomologist, Experiment Station.

Washington: "Up to the present time, I have never come in contact with this insect in western Washington."—Professor Trevor Kincaid.

Professor T. D. A. Cockerell says that he has no record of the insect's occurrence in New Mexico.

The species was first recorded in Canadian orchards in 1898. Prof. J. M. Swaine, reporting for the Canadian Division of Entomology, says: "The species is common and injurious in the fruit district of Southern Ontario, but has not been reported recently from any other province of Canada and does not appear to occur at all in Quebec province."

The beetle was apparently disseminated over the whole of Ohio by 1895, and was probably introduced several years earlier. Professor Webster gave some notice to it in Bulletin 68 of the Ohio Station. The number of reports by years from Station correspondents as shown by the Station letter copy-books, beginning with 1895, are as follows:

1895—5	reports	1901—0	reports	1907— 3	reports
1896—8	"	1902—0	"	1908— 6	"
1897—3	"	1903—6	"	1909—12	"
1898—4	"	1904—3	"	1910—13	"
1899—1	"	1905—0	"	1911—39	"
1900—5	"	1906—0	"	1912— 7	"

It appears from this table that there have been two periods of unusual abundance, the first about 1895-1900 and the second from 1908 to 1912. The later outbreak may not have been more severe nor more general than the first, as the ratio of the largest number of reports for any year to the total correspondence received by the Department for that year is practically the same. The distribution of the reports, geographically, indicates, without doubt, that the insect occurs in every neighborhood within the state.

DESCRIPTION

Adult beetle: A little less than one-tenth inch (2-3mm.) long and one-third as wide, color black except the tips of the wing covers and lower parts of the legs, these being russet-red. The wing covers are grooved, the depressions being fitted with lines of minute punctures. The posterior margins of the wings have a saw-toothed edge. The body, in general, is covered sparsely with short pale yellowish hairs. The thorax is smooth and shining, showing numerous punctures under a hand lens and is lined along the posterior and lateral borders with a slightly elevated line.

The head is vertical, the antennae or feelers short and strongly clubbed. For the use of professional entomologists, I append by footnote a brief technical description prepared by Mr. J. L. King.* A fuller technical description by Dr. S. A. Forbes can be found in the 17th Report of the State Entomologist of Illinois for 1889 and 1890.

Larva: The larva is a footless grub, cylindrical, whitish, often tinged with pink, transversely wrinkled, with a small or yellowish head. The anterior part of the body, including the thoracic segments, considerably enlarged, the posterior portion gradually tapering to the end and reflexed or bent downward as viewed from above

*Adult. Small beetle 2-3mm. in length, elongate oval in form, pitchy black with feeble reflections. Head globular and hairy, densely punctate above, genae finely striate, epistoma bearded, eyes elongate, mandibles stout, antennae chestnut brown, terminating in a laminate club. Thorax with disk of promotum sparingly hairy and coarsely punctate, sides slightly carinate. Elytra longer than the thorax; tapering slightly and serrate at the tips, surface with punctations in rows appearing as striae, punctations at intervals bearing erect whitish setae. Abdomen reflexed dorsad. Legs dark brown, tibiae, as in all the family relatives, uncinnate at the inner apical angle.

the back. The mouth parts are rusty-reddish, the antennae small, two-jointed and located at the base of the mandibles. When newly hatched, the larvae are only about .56mm. long, but when full grown are from 3.5 to 4mm., or about one-tenth of an inch long.

Pupa: The pupa is a trifle less than one-fourth of an inch (3-3 5mm.) long (measurements taken from formaldehyde specimens) and dull white to slightly pinkish in color. The lower portion of the mandibles and sometimes the tips of the tarsi are brownish. Wing pads grooved, obliquely appressed against sides of abdomen, several segments of abdomen beyond hindermost reach of the pads.

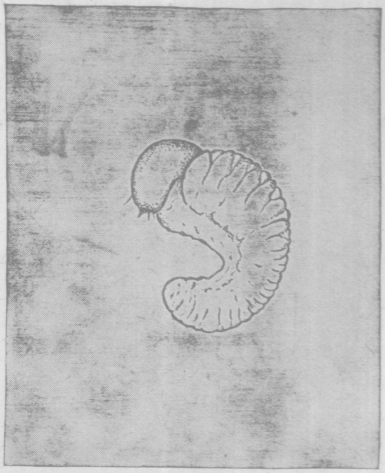


Fig. 1. Young larva, greatly enlarged.

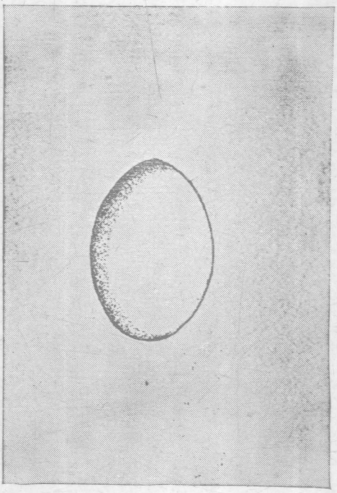


Fig. 2. Egg, greatly enlarged.

Egg: The eggs when first deposited are milky white, later becoming translucent or clear. They are oval in form, about .52mm. in length by .36mm. in width. Mr. Lowe's measurements are practically the same, .574mm. by .4mm. as an average.*

LIFE HISTORY AND HABITS

HIBERNATING LARVAE

At the ends of the larval burrows in dead wood, cells are excavated, generally in the sapwood but sometimes in the outer bark, and in these cells the larvae hibernate, pupating in early May. Larvae in the sapwood cells are apparently mature by the 10th of April and are not feeding, and it is presumed that the majority of these are full fed when they commence hibernating in the fall. Some of those in the outer bark are smaller than the average and have a pinkish

*Bull. No. 180, New York Agricultural Experiment Station, Geneva, N. Y.

tinge. When removed to suitable clean vessels, and left for a few hours, fine filaments of reddish-brown excrement may be found protruding from the ends of the abdomen of these retarded larvae, this, with the pinkish tinge of the abdomen, indicating that they have commenced feeding by April 10th or earlier.

In 1912, pupation had commenced at Gypsum, Ohio, by May 7, numerous pupae and larvae being found in the cells in the sapwood and a few in the outer bark. By the 18th of May, the pupation period was about closed. Only a few larvae could be found either in the field or in the laboratory breeding cages, and many of the pupae showed dark eye spots and mandibles. Other specimens, more advanced, showed these characteristics and also the dark chitinous plate of the thorax and darkening of the abdomen. On May 19, the first beetles emerged. Assuming these to have come from some of the earliest pupae noticed, about May 7th, we have 12 days or thereabouts as the pupal period. The mean temperature for the month of May was 60.7° F., or 1.5° F. above the mean. The temperature was 37° F., May 13th, and the weather for the entire period would be called cool. In July, the exact pupal period was established with two laboratory specimens which we will designate as A and B. The record, by dates, is as follows:

A

July 7, Larva
" 8, "
" 9, Changed to pupa
" 10, Pupa white
" 11, " "
" 12, " "
" 13, Eyes showing dark
" 14, Mandibles dark, also some other parts
" 15, Thorax and abdomen dark
" 16, Very dark
" 17, Beetle emerged

Pupal period 8 days

B

July 7, Larva
" 8, Changed to pupa
" 9, Pupa white
" 10, " "
" 11, " "
" 12, Eyes slightly dark
" 13, Eyes dark, also body parts
" 14, Thorax and abdomen dark
" 15, Beetle emerged

Pupal period 7 days

The following record gives the historyof five pupae from larvae which were removed from their cells and kept in moist chambers:

July 8, Larvae 5 in number, a, b, c, d, e
" 9, Larvae 5 in number
" 10, 3 pupae, a, b, c
" 11, 5 pupae, a, b, c, d, e
" 12, 5 "
" 13, 5 "
" 14, 5 "
" 15, 5 "
" 16, 5 "
July 17, b pupal period completed in 8 days; d, pupal period completed in 7 days
" 18, e, pupal period completed in 8 days
" 19, a and c, pupal period completed in 10 days

Much fuller breedings were made in the season of 1908, the pupal period being determined with several hundred specimens. The period for the spring brood derived from the winter larvae ranged from 8 to 18 days; for the summer brood from 7 to 12 days. In 1908, the first pupa was found April 20th, on peach. Several more were found during the next ten days and by the 30th were forming in the laboratory. May 20th appeared to be about the date for the maximum number of pupae belonging to the winter generation of larvae. June 1st was the latest date that a pupa of the winter generation was found. In 1909, pupae were found in the laboratory cages June 12th, and, as beetles belonging to this generation continued to emerge for some time later than this, it is presumed that the pupal period is in some years extended to about the middle of June. These laboratory specimens, in cages, in an unheated room indoors, were doubtless a little later in emerging than if they had been in the outdoor sunshine.

The earliest pupa of the summer generation was found July 6, 1908, and they were plentiful two or three weeks later. Pupae could be found from this time onward until late October, but so far as we have been able to determine, they all belong to the same generation. The statement* that sometimes larvae, pupae and adults may all be found in the same wood during the winter, is probably correct for localities in the southern part of the United States, but only larvae can be found in northern Ohio during the winter, and this observation corresponds with Dr. Forbes' findings for Illinois. The full grown larva burrows well out toward the outer bark before pupating and fills the outermost part of the burrow with a cap of frass or saw-dust. It then pupates with its head toward the cap, or in position to eat its way out through the bark when it attains the beetle stage.

FIRST GENERATION OF ADULTS

In 1912, the first adults were taken May 19; in 1908, May 20, and in 1909, the earliest record was of specimens appearing in a breeding cage, June 3. Mr. Wilson observes that at Longley, 50 miles south of Lakeside, "The beetles seem to reach the adult stage somewhat before those from Lakeside. Upon changing from pupae to beetles, the insects remain inactive for a day or so, merely moving their legs and antennae about. The eyes, mandibles and more heavily chitinized parts may become slightly tinged with brownish in the pupa stage, and these, with the antennae, are the first parts to show dark in the newly emerged beetle; next the thorax darkens,

*Circular 29, Bur. Ent., U. S. D. A.

then the tip of the abdomen, and gradually all parts assume brownish, later turning black. The beetles now eat their way out through the bark. Very few specimens with light-colored elytra are encountered outside the pupal cells, as they have nearly always become hardened and black before venturing from their burrows. About 10 a. m. they commence leaving their burrows and by 1 o'clock, the maximum rate of emergence is reached; a decline in the rate now commences and the exits for the day are practically over by 3:30 p. m., very few beetles ever appearing later than this. The beetles are much more sprightly in their movements over the bark than *Phloeotribus liminaris*. They are often seen running rapidly up and down the trunks and larger branches of infested trees, the males in quest of the females, and the females seeking for places to start their burrows. As soon as they emerge, the beetles immediately begin work on fresh wood. Both entrance and exit holes of the beetles are generally more numerous on the sides and under parts of the branches than on the upper surface, but they are not infrequent in the latter situation. The flight of these beetles is quite strong and they are doubtless capable of flying for a considerable distance, especially if aided by the wind. They readily take flight from breeding jars and from windows into the open. They are sometimes seen flying in the open and have been found on the inside of car windows, this indicating that they entered the cars while in flight through rather open spaces.

Food Habits: The female beetles obtain most of their food while boring through the bark to and from their brood chambers. Bark makes up the greater part of their diet, while the true wood forms only a small portion of the food. Beetles confined for a few days without food readily feed on fibers of moist bark.

Construction of the Brood Chamber: Very soon after issuing from the wood the females of the first generation begin the construction of their brood chambers. This work seems to be the most important of all their activities, since both feeding and reproduction are thereby accomplished. The males have no special mission except to attend the females. After a satisfactory place has been selected by the female, she starts gnawing with her powerful mandibles, during which process she clings tightly to the bark. While gnawing, her shear-like jaws may be seen rasping off fragments of bark while the ball-like head moves freely in the socket of the prothorax As the work advances, the beetles lift their bodies at all angles until they appear to stand upon their heads, for these entrance holes are made almost at right angles to the surface of the bark. Upon reaching the sapwoood, the burrows turn abruptly

upward and are continued with the inner half of the burrow in the sapwood, the outer-half in the bark. The rate of burrowing varies considerably; some beetles will gnaw a space the length of their body in 1½ hours, while it takes others 2 to 4 hours or more. The great majority of the entrance holes (about 75 percent) are made through the lenticels or bark pores. The remainder are started at abrasions or points of mchanical injury, at rough places, etc. The insects must find roughened or elevated places against which they can brace their feet to commence work, and also prefer such spots as the lenticel pores because of the corky texture of the cells which offer comparatively little resistance to excavation.

The holes in smooth bark are exit holes. These are generally arranged as an irregular and imperfect oval, each leading from the extremity of a larval gallery. An examination of Fig. 3 will make clear why the terminals of the galleries and, therefore, these exit holes form an imperfect oval.

Peach trees, cherry trees, and plum trees, badly attacked, are apt to exude gum in lage quantities through the entrance holes. Apple and pear, when attacked, do not gum so freely, generally not at all. While the number of trees of the different varieties of fruits which we were able to observe may have been insufficient to warrant very definite or final conclusions, the indications are that plum, peach, cherry, apple and pear may be considered as preferred hosts in about the order named. Weakened trees in uncared-for orchards are most apt to be attacked, but healthy trees in the best cared-for orchards are not always wholly exempt. The Lesser Peach Borer, *Sesia pictipes*, the Peach Bark Beetle, *Phloeotribus liminaris*, as well as some other insects and diseases, may produce a very similar condition; therefore, a careful examination is necessary to determine if the Fruit Bark Beetle is the culprit. If small pits, cut through the lenticels into the sapwood are found beneath the gum this may be taken as presumptive evidence that either the Fruit Bark Beetle or the Peach Bark Beetle did the work, generally the preceding season. The Fruit Bark Beetle makes such burrows for the purpose of feeding, or possibly as the beginnings of brood chambers which are soon abandoned because of untavorable environmental conditions. The Peach Bark Beetles make quite similar pits, but with enlarged cells in which to hibernate during the winter. Possibly the excessive quantity, or the adverse quality of the gum exuding, causes the females to abandon such burrows as not suitable for the rearing of their young. Damage begun in this way however, and continued for a few successive seasons, may weaken the trees to such an extent that they may become exactly fitted for incubation purposes.

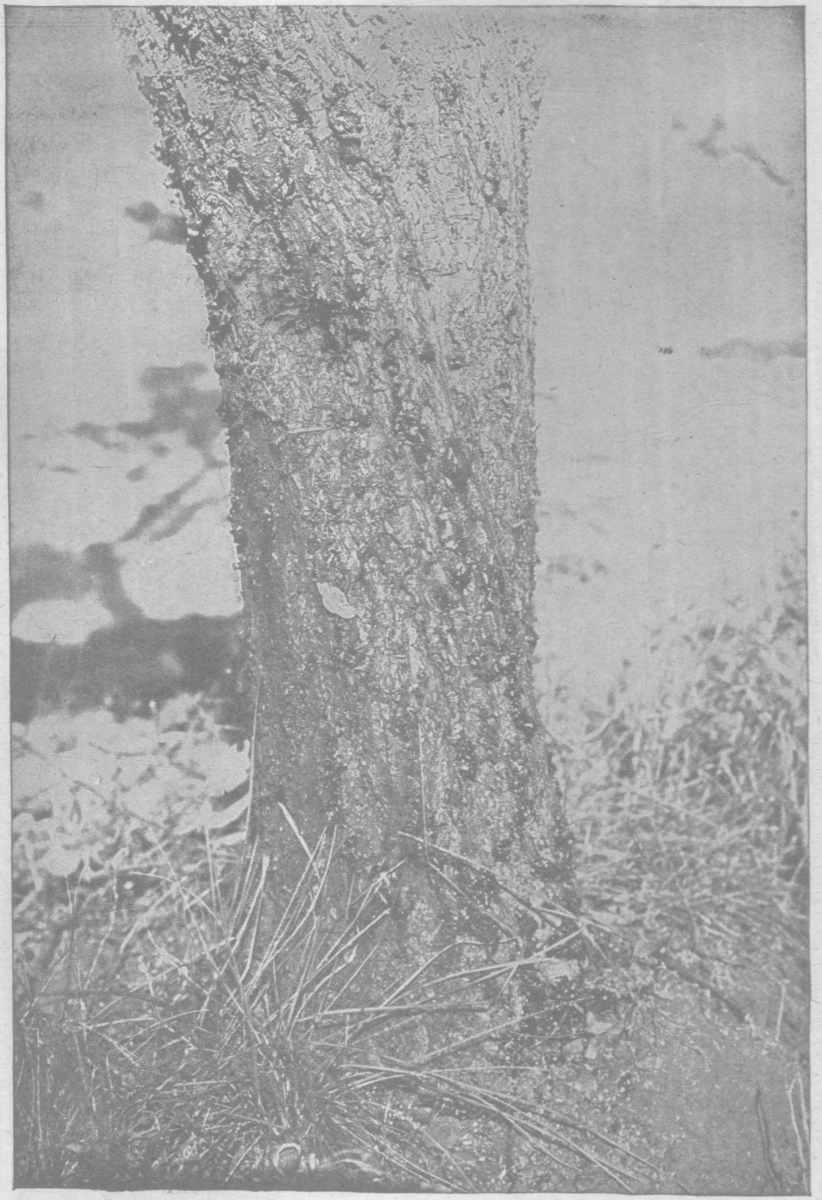


Plate III. Gumming from attack of Fruit Bark Beetle on trunk of old tree.

At the point where the entrance burrow meets the sapwood the chamber bends upward and extends approximately parallel to the axis of the trunk or branch in which it is made, and may reach a length of two inches or more, but the usual length lies between ½ inch and 1½ inches. The average length is very close to 1 inch. Where work is continuous, from 7 to 10 days seems to be about the time necessary to complete the chamber, but it is often, perhaps even generally the case, that the work is not continuous but intermittent, and that an indefinite, but longer period than the one just stated, is required.

Mating Habits: As soon as the female has lengthened her burrow enough to permit the entrance of her whole body, she ceases work long enough to accomplish mating. A male may be in waiting at the mouth of the burrow, in which case copulation occurs at once, or it may occur even before the female has excavated enough burrow to receive her body, or sometimes before she has commenced any burrow at all. Usually, however, the female ceases work and protrudes the end of her body from the entrance, and thus awaits the male. Copulation then takes place with the male outside the burrow and the female within it. In other cases mating is performed with both insects inside the burrow, with only the head of the male projecting. The only copulation that was timed required 20 minutes for its completion. The males can often be observed waiting for hours at a time at the entrance to the brood chambers. They seem to become restless at times and enter the burrow for a short distance and then back out. In a breeding jar, 19 males were counted on a single branch, all waiting at the same time at the entrances to the brood chambers in the bark. A number of these chambers were opened and found to contain female beetles, eggs, and very young larvae. Sometimes one male will drive another away from the entrance at which he is waiting. It seems probable that mating takes place several times during the construction of the brood chamber, and the length of the brood chamber and the number of eggs and larvae produced by the female may, perhaps, depend on the number of matings experienced in her lifetime.

Egg-laying and Galleries of the Larvae: Egg-laying or oviposition occurs soon after mating. The female commences the excavation of the brood chamber proper after copulating, the floor of it in the bast or sapwood, and the roof in the bark. Small niches or cells are made along the side walls, half in the bast and half in the bark; each is just large enough to receive an egg. After many attempts, Mr. J. L. King was fortunate enough to observe one female in the act of oviposition. The brood chamber had been opened by means of a sharp knife and a small flap of bark was lifted from the top of the brood chamber. A tiny egg-niche had been

made by the beetle before the burrow was opened. After some hesitation the beetle backed out of the burrow to the outside where she immediately turned about and backed into the brood chamber. Upon reaching the locality of the niche, she distended her abdomen and with it seemed to be feeling along the wall of the burrow as if hunting for the niche. After a few moments of exploring the niche was located. The tip of the abdomen was then held within the niche and a single tiny, translucent egg was deposited therein and left standing at right angles or endwise to the burrow. The beetle then crawled out of the burrow and entered again, head first, and upon reaching the niche she covered the egg with fine frass. The mouth-parts seemed to be used to cover the eggs; after covering them over the insect remained quietly within the burrow. There are two lines of eggs, one on each side of the burrow; the eggs are sometimes almost touching each other. The egg-lines extend backward into the burrow until the last eggs laid are practically out to the terminal corner of the burrow. It would be impossible for the female to place these newest eggs in position without backing into the burrow to do it. The frass-packing over the eggs practically makes an inner smooth tube in which the adult lives while the eggs and young are without. Each young larva commences the construction of a gallery outward from the brood chamber soon after it

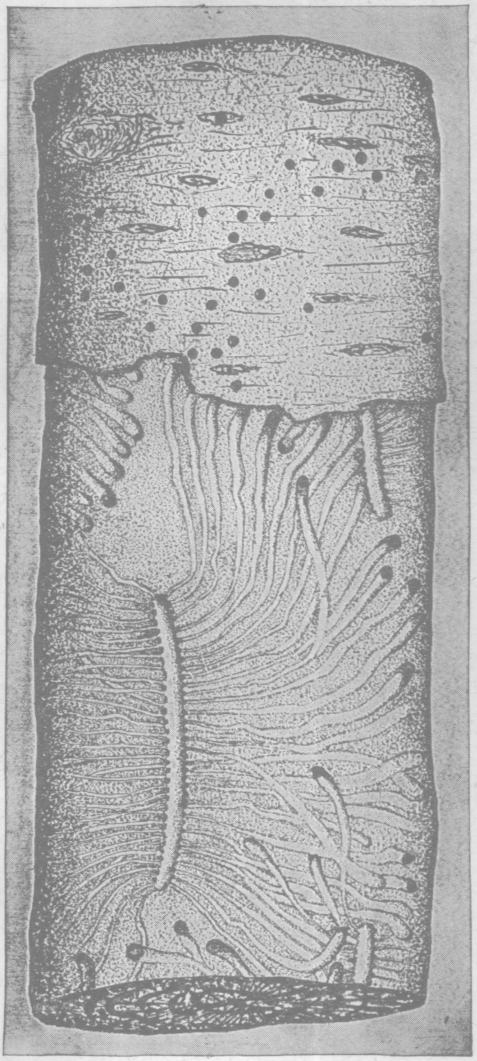


Fig. 3. Brood chamber and galleries of the Fruit Bark Beetle, *E. rugulosus*, natural size.

hatches, generally extending it at a right angle if near the middle of the chamber, and somewhat obliquely outward if originating near its end. The galleries diverge more and more from each other as they are enlarged in diameter, to accommodate the growing grubs. The general form of the completed burrow with its finished radiating galleries is shown in the accompanying drawing. (Fig. 3.) The flooring of the galleries, like that of the main chamber, lies in the sap-wood while the over-head roof is in the bark. These galleries are completely filled with a reddish-brown frass or excrement, derived from the bark. They vary in length from less than an inch to three or four inches or more in length, depending on the kind of wood used for incubation, and also on the crowding of the galleries, the meeting with obstructions or with old galleries of earlier generations, etc. The same area may be crossed and intercossed by the galleries of several different brood chambers. In cases of bad infestation the bark over the whole trunk and larger limbs may be so loosened that it falls away, or may be torn away by woodpeckers searching for the grubs, leaving the inner wood exposed and bare. Such an infestation means the speedy death of the tree, if it occurs in living wood. The areas generally chosen are dead or diseased patches of bark on otherwise healthy trees, or else the trunks and branches of weak and unhealthy trees. Egg-laying begins as soon as the burrow reaches the sapwood in case of those females which have mated, while some burrows from ⅜ to ½ inch long do not contain eggs, though females may be present. These females probably have not yet mated. The number of females appears to greatly exceed the number of males.

The period of incubation, so far as could be determined, is from 3 to 4 days. Of 7 eggs, laid in July and kept under observation, 3 hatched in 4 days and the remaining 4 in 3 days. The number of eggs deposited by one female in one brood chamber ranges from 20 to 163 or more. From counts made on 19 brood chambers, June 26, 1908, the minimum number was 30, and the maximum 112, the average 76. June 29, 1908, counts were made on 8 brood chambers and the minimum number of eggs found was 47, maximum 132, average 91. Counts taken on earlier dates gave smaller numbers, presumably because not all of the eggs had yet been laid. The earliest date of discovery of eggs in 1908 was June 7, but young larvae were found May 28 in 1912, indicating that egg-laying may commence about the 20th to the 25th of May in some seasons.

The entrance to old burrows is quite generally plugged with the body of the dead female. Whether she comes to the entrance to obtain fresh air when she is finally exhausted and life is flickering out, or whether she instinctively devotes her carcass as a protection against the entrance of parasites into the burrow can be only a matter of speculation.

FIRST GENERATION OF LARVAE

The newly hatched larvae are only about .55mm. long. Soon after the commencement of feeding a pinkish tinge overspreads the body due to the bark which they eat.

In 1908, the first larvae produced by the first brood of beetles were found June 13th. One larva was at this time 1-4 inch away from the burrow. Fourteen very young larvae were found to have hatched in the same burrow on this date. The larvae had become numerous by the end of June. They could be found from this time on until winter, because of some overlapping of the first and second broods.

In 1912, some larvae hatched May 28 and were full grown July 3, a period of 36 days being required to reach maturity. Another lot, hatching June 5, matured July 7, or within 30 days. When full grown, the larvae form pupal chambers at the ends of the larval burrows. These pupal cells are formed in the sound sap-wood just beneath the bark and are just deep enough to conceal the larvae. The entrance into these oval cells is plugged with sawdust or frass, having the inner portion of the plug very compact, the small particles being apparently gummed together by a secretion from the larva. After finishing the cell, the larva turns about and rests with its head toward the plug or cell-opening in which position it pupates, ready to bore through the bark to the outside as soon as it becomes adult.

Measurements in millimeters taken of a series of larval heads and mandibles indicate the probability of four stages or instars in the larval life as shown by the following table:

TABLE I. Showing measurements of the instars.

First instar			Second instar			Third instar			Fourth instar		
Length of head	Width of head	Width of mandible	Length of head	Width of head	Width of mandible	Length of head	Width of head	Width of mandible	Length of head	Width of head	Width of mandible
.26	.20	...	.36	.32	.12	.52	.48	.20	.72	.60	.28
.28	.22	.08	.32	.28	.12	.48	.40	.20	72	.60	.24
.24	.24	.1	.36	.28	.12	.56	.50	20	76	.64	.28
.26	.22	.08	.36	.30	.12	.42	.44	.20	.62	.54	.22
.28	.26	.12	.32	.28	...	.48	.44	...	.60	.50	.22
.28	.26	...	.30	.26	...	.38	.32	...	.64	.60	.24
.28	.24	.08	.32	.28	.12	.40	.36	...	60	.52	.20
.28	.20	.08	.32	.28	.12	.48	.40	...	72	.64	.28
.24	.20	...	.36	.32	.12	.48	.44	.20	72	.64	.28
.26	.24	.12	.36	.32	.12	.56	.50	.22	.76	.72	.28
.28	.26	...	.32	.28	.12	.52	.50	.20	.60	56	.24
.26	.20	.08	.36	.32	...	.46	.36	.20	64	.56	.28
.28	.26	...	.36	.28	.12	.40	.36	...	72	64	.28
.28	.24	...	.36	.32	.12	.44	.36	.20	72	64	.28
.28	.24	.08	.36	.32	.12	.44	.36	.20	76	66	.30
.28	.26	.08	.40	.36	.12	.44	.32	.	72	.64	.28
.28	.24	.08	...	...	...	.38	.32	.	72	.64	.28
.26	.24	. .	. .	. .	.	..	...			.	...
.28	.26	.08	. .	. .	.	.	.	.	.	..	...
.24	.20	.08	..	. .	. .	.	..	. .		.	...
Av. of 20 spec. .267mm.	Av. of 20 spec. .238mm	Av. of 13 spec. .087mm	Av. of 16 spec. .323mm	Av. of 16 spec. .30mm.	Av. of 13 spec. .12mm.	Av. of 17 spec. .461mm	Av. of 17 spec. .407mm	Av. of 10 spec. .20mm	Av. of 17 spec 690mm	Av. of 17 spec. 608mm	Av. of 17 spec. 260mm

The individual measurements in nearly every case, as may be seen from an examination of the table, approximated some one of the averages closely enough to enable us to refer the specimen without much doubt to the corresponding instar as classified in this table.

MIDSUMMER BROOD OF PUPAE

As noted in the preceding paragraph, the pupal stage from the first generation of larvae is entered upon in early July or thereabouts. Since the pupal period for this season is generally from 7 to 10 days, or slightly more or less, the adults of the second brood begin to appear about the middle of July or a little earlier.

SECOND GENERATION OF ADULTS

We have already observed that there is some overlapping of the two generations of insects. The early beetles start about the middle of May, a few specimens coming earlier, and the brood is practically over by the middle of June, though a few females linger for nearly a month longer. When the males become aged and decrepit they drop to the ground and die, while the female dies, as a rule, resting in the mouth of her burrow. The second or summer brood of adults begins about the middle of July and they continue to issue until late August or early September. The accompanying curve (Plate IV), prepared by Mr. King, shows the rise and fall in numbers of the adults for the different dates of the season; the counts were made from specimens issuing from the laboratory breeding jars during the summer of 1912.

Beetles were found as late as Oct. 29, 1912, and were not infrequent in breeding cages until Oct. 19, 1908. Unhatched eggs could be found in the burrows until late in September, 1912, and larvae and pupae until late in October. These belated September eggs are presumably laid by stragglers of the second brood, though it is not impossible that they represented a partial third brood. Beetles emerging later than September have not been found laying eggs, and since no other stage than larvae can be found in northern Ohio during the winter or early spring, we are obliged to conclude that in all probability these late issuing beetles perish upon the coming of cold weather without reproducing.

HIBERNATING LARVAE

Most of the larvae must have been full fed at the outbreak of winter and made cells in the sapwood, then sealed themselves in by stopping the burrow connection with a cap of compact frass. They were thus in position to pupate and bore out through the bark as adults during the following May and June.

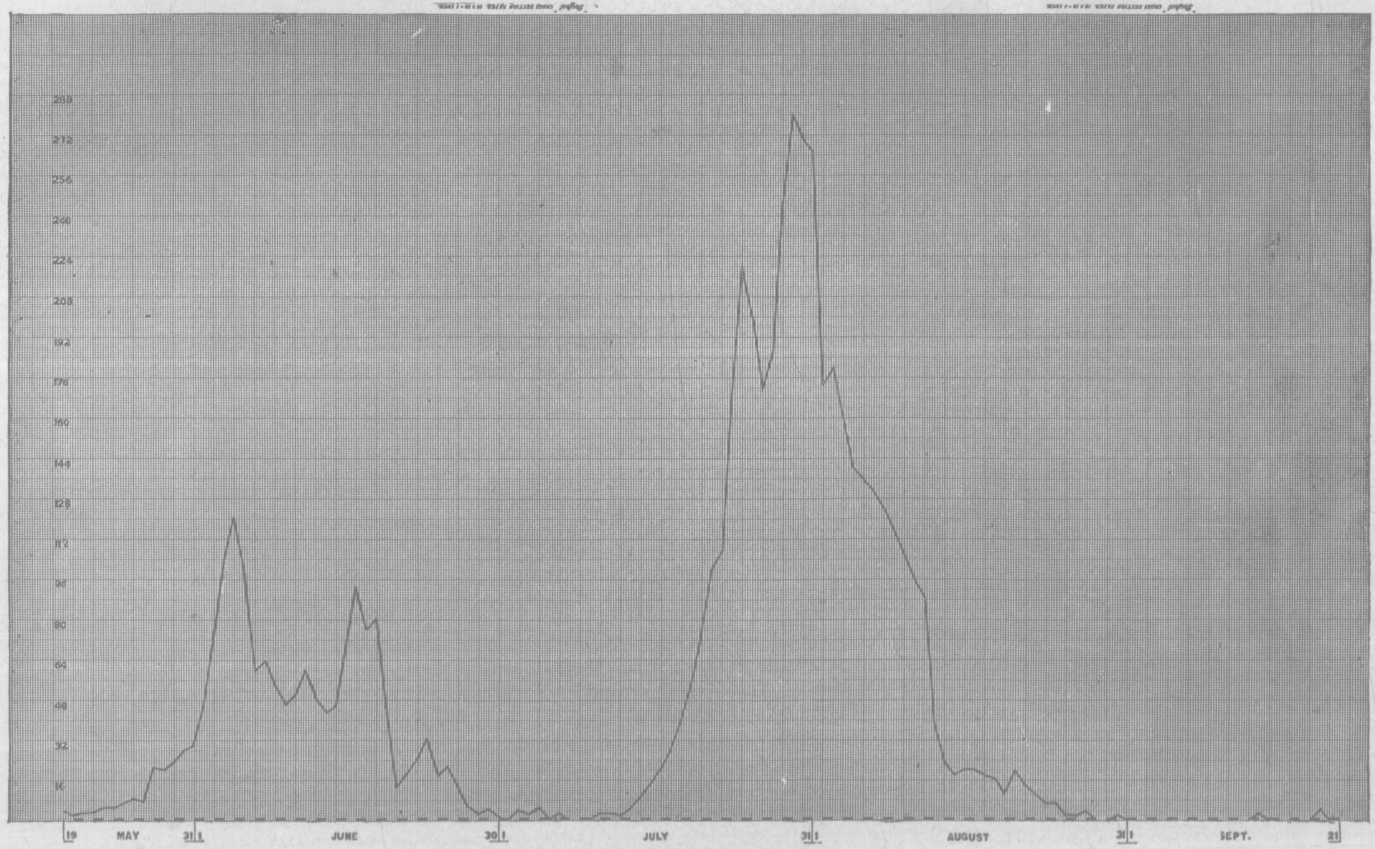


Plate IV. Curve showing rate of emergence of Fruit Bark Beetle, *E. rugulosus*, during summer of 1912. One small square upward represents one beetle emerging in the observation breeding cage and four squares longitudinally represent one day. The first brood is seen to be at its climax about the 5th or 6th of June and the second about the 29th or 30th of July.

Some of the larvae are found under the bark, and these probably feed until they become torpid and, as recorded at the beginning of the life cycle, they resume feeding in the spring. The record of the life cycle is herewith completed and connects back with the paragraph on "Hibernating Larvae," page 11.

CHARACTER OF INJURY

Reference has already been made in the "Introduction" and also in the paragraph on "Brood Chambers" to the general and also to some of the particular phases of injury caused by this bark beetle. Generally speaking, the beetles confine their attack during the early part of the summer, from May until late in June, to winter-killed and dying trees. The winter of 1911-12 was very severe throughout Ohio and many peach trees in the Lake District were weakened or killed. Many trees came into bloom and leaf, then withered and died. Trees in low, undrained orchards specially suffered, these, and also many that were weakened by the Peach Tree Borer, *Sanninoidea exitiosa*, dying. These dead and nearly dead trees formed the chief breeding places for the beetles. Attacks on such trees cause little or no gum flow. If sufficient life is still in the tree to cause an outflow of gum, very few of the brood chambers will be found to contain larvae. While larvae may sometimes be found in large numbers on living trees, close examination will show that they are located in a deadened or nearly dead area, and that few or none can be found where there is real live wood with sap coursing through it. However, if no damage at all were ever in any way inflicted upon living trees, the insect could not be classed as specially harmful. Vigorous, healthy trees are attacked by the adult beetles in late summer and fall, causing a copious gum flow and a gradual weakening. Entrance into the bark is nearly always made through the lenticels or through rough places and abrasions. From each hole exudes a quantity of gum which gradually accumulates outside. Where the beetles are exceptionally numerous, because of favorable breeding conditions in the neighborhood, and the supply of weakened trees has become exhausted, they may concentrate upon healthy trees to such an extent that these gradually become weak and furnish within one or two seasons a perfect condition for incubation. We have sometimes had reports of vigorous, healthy trees being killed outright in a few weeks by such onslaughts, but thus far have not been able to confirm the reports. However, we strongly suspect they are sometimes correct.

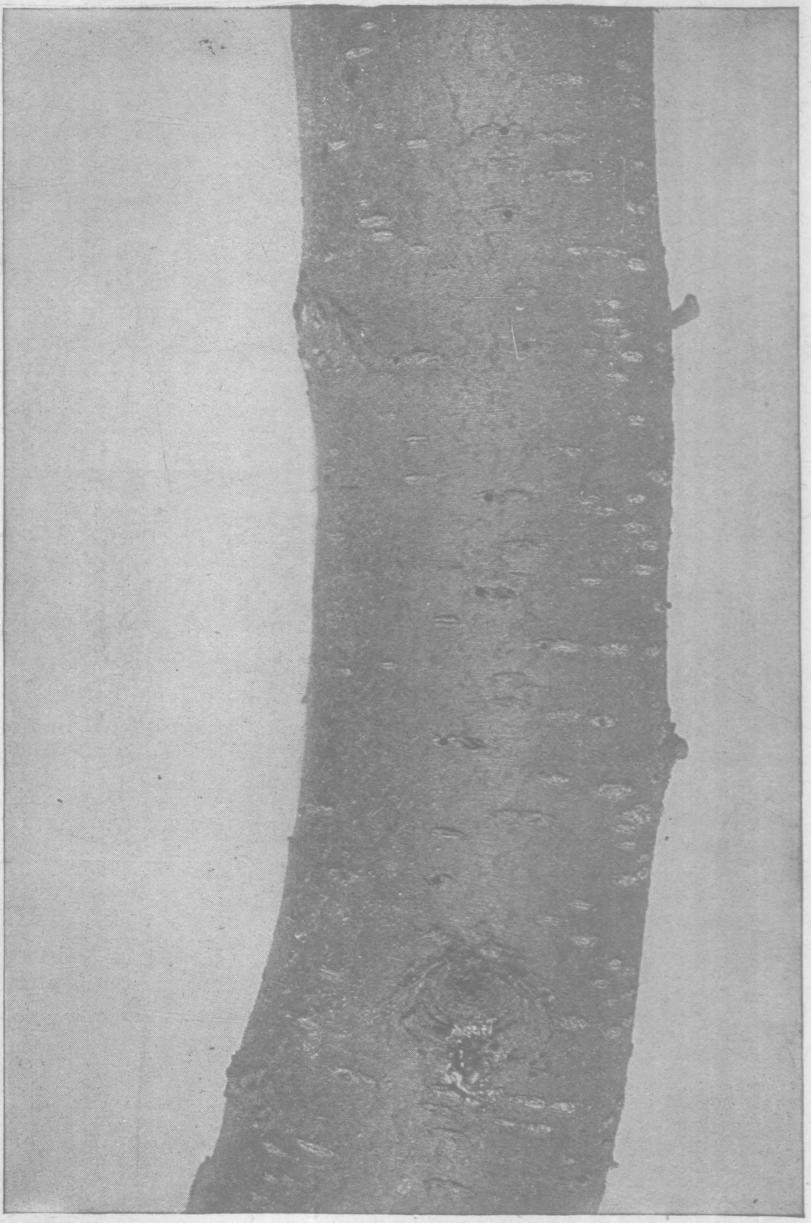


Plate V. Entrance holes of Fruit Bark Beetle, *E. rugulosus*, through lenticels and roughened places.

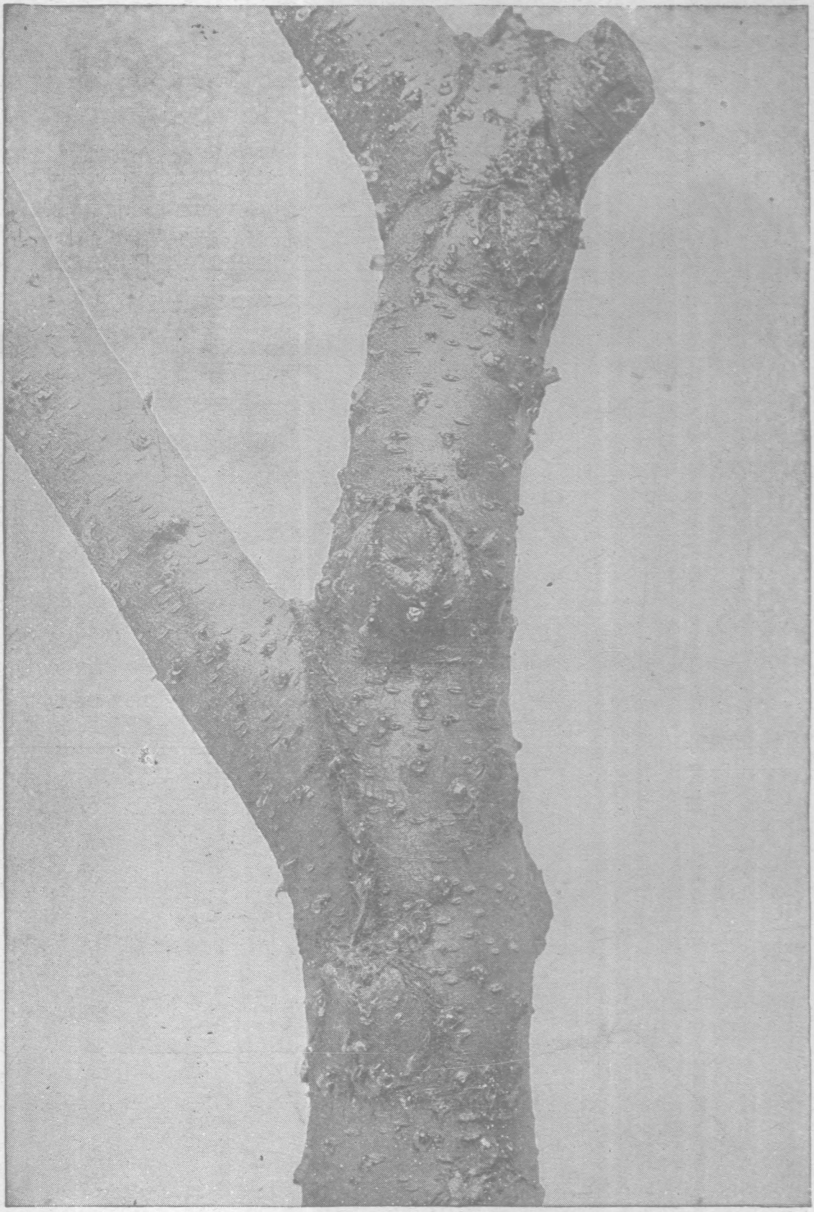


Plate VI. Gum exuding from feeding punctures of *E. rugulosus*.

In 1912, these attacks on living trees were first noted Aug. 14. The beetles were making these feeding chambers chiefly on branches two or three years old, and into the new twigs. On the twigs the beetles were boring shot holes in the crotches of the leaves and of the winter buds or in leaf scars. A few beetles could be found embedded in the exuded gum-drops like fossil insects in amber. Later in August more trees were found with the beetles at work on the trunks and larger limbs. Here, again, according to the seemingly invariable rule previously stated, the entrance holes were made through the lenticels and roughened spots on the bark. From such trees more than a gallon, in some cases two or three gallons, of gum would be adhering to the bark or collected into masses near the ground. Sometimes both *E. rugulosus* and *P. liminaris* are found working at the same time on the same trees.

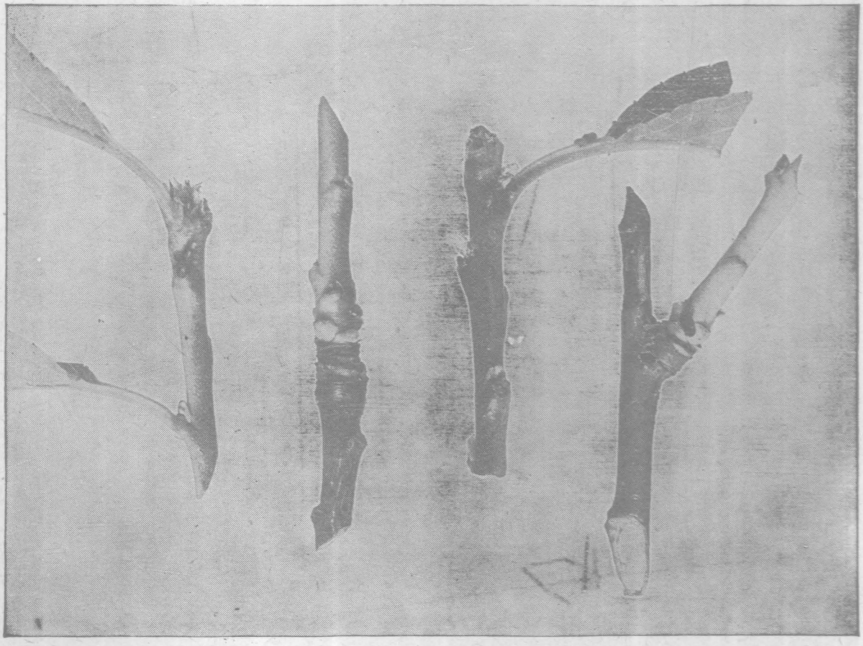


Fig. 4. Note beetles entering at bases of buds and in crotches of the leaves.

Under date of July 18, 1908, Mr. Wilson noted that all the dead and dying limbs of peach, plum and cherry were loaded with larvae, pupae, and beetles about to emerge. It was impossible to find wood with which to supply the breeding cages without cutting branches from perfectly healthy trees. One tree that was apparently in a healthy condition the preceding fall was attacked and then deserted

as the gum quickened its flow; it poured out through the holes as if through a strainer. Later, the same season, the beetles apparently made a second attack and completed the death of this tree. It is upon this instance as well as upon reports from correspondents, that we base our expressed opinion that perfectly healthy trees may sometimes be killed in a few weeks and before any brood chambers are constructed. July 30, 1909, Mr. L. L. Scott noted that "some of the weaker trees showed some beetles attacking them, notably on those parts of the trees which were partly dead or dying. On more healthy parts of the same trees the beetles had made their attacks, but in most instances, had been repulsed by the copious exudations of sap. Such attacks usually extend well into the tops and smaller limbs of the trees and, in several instances, the loss of sap was great enough to so weaken the trees that the egg burrows were completed without the beetles being driven out by the flow of sap. In all cases, only the weaker trees are attacked; those which are healthy and show a strong and luxuriant growth with smooth bark, are in no case to be found infested."

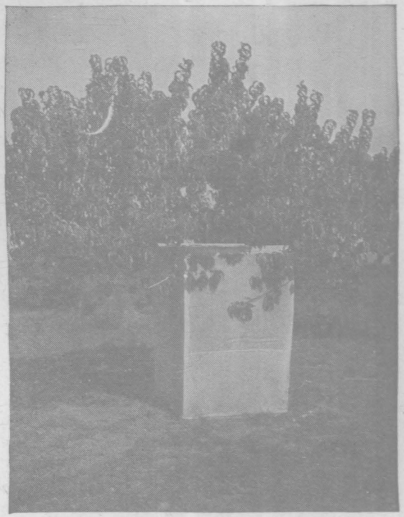


Fig. 5. Cage for confining beetles to trunk of a healthy tree.

Fig. 6. Interior of cage about healthy peach tree a few weeks after arranging. Note the dead wood piled at base and gumming of the trunk.

In order to test the foregoing question experimentally, Mr. King was instructed to construct a suitable cheesecloth cage about a vigorous, healthy tree and pile inside it large quantities of infested

wood so that the beetles, upon emerging, would be obliged to attack it in excessive numbers, both to obtain food and to oviposit, if oviposition were possible under such circumstances. Accordingly, July 13, 1913, a cheesecloth box-cage was constructed about the trunk and over some of the lower branches of a vigorous, healthy Elberta peach tree, the lower branches being cut square across at a uniform level to permit their being enclosed. The trunk passed out through the top-center of the cage and carried the larger part of the untrimmed top above the cage under ordinary normal conditions. Then at the base of the tree within the cage was piled a large quantity of dead wood containing larvae of *E. rugulosus*. The tree used was 8 or 9 years of age, about 10 feet high and had approximately 12 feet spread of top. It was in vigorous health. The cage was about 5 feet high, 3⅓ feet wide and 4½ feet in depth from front to back. The following notes record the result of the test:

"Aug. 7. Beetles emerging and attacking tree, always starting at pores in the bark. Weather very dry. Little bleeding at punctures.

Aug. 19. Beetles have attacked tree badly, causing a copious flow of gum from most all the lenticels, though the upper part of the tree shows on difference in color, nor any symptoms of a weakened condition.

Sept. 8. Though the tree has been badly bled, it no doubt will survive. The leaves on the small twigs in the enclosure have all been killed by beetles boring in at the base of the petiole, or behind the winter bud. No larvae were found within the tree. A few of the beetles oviposited in the dead wood which was left in the cage.

All the fruit ripened normally on the tree."

Though the result in this experiment was negative, we are not convinced that it is impossible for the beetles to kill healthy trees in a brief period. The fact that all small limbs and twigs within the cage died outright suggests that if the entire tree had been enclosed so that all the twigs and smaller limbs could have been attacked the whole top might have quickly succumbed. The purpose in enclosing only part of the tree and leaving most of the top outside the cage was to avoid complicating the questions of injury by shade and impeded circulation of the air with bark beetle damage.

The following quotations from other investigators are of interest in this connection:

Professor S. A. Forbes in his 15-17 Illinois Report(1885-90), pp. 1-12, says: "Two vigorous peach trees which showed the characteristic perforations very thickly placed, did not have the bark undermined, but these trees had bled very freely, the gum having run down the trunks to the ground in considerable quantities."

Again, in conclusion we note from Dr. Forbes: "Certainly, however, in Illinois, so far as one may judge from observations already made, plum and cherry trees which would pass as healthy, even those still young and thrifty, sometimes suffer serious injury. On the other hand, we have had occasional instances of a vigorous attack made on the trunk and branches of the peach which was apparently repelled by the great effusion of sap, so that no injury had resulted, except such as would follow from this profuse bleeding."

Mr. V. H. Lowe notes serious injury caused by *E. rugulosus* in 1899 in Bulletin 180, N. Y. Agricultural Experiment Station (Geneva, N. Y.), 1900. On page 122, Mr. Lowe notes injury to healthy cherry trees by the formation of round holes at the spur of the leaves. He states that one-fourth to about three-fourths of the leaves were dead, and that a fourth survey in the vicinity of Geneva, and in Monroe and Niagara counties, showed that this species had caused extensive injury during the season, then past, to healthy vigorous trees.

Dr. John B. Smith, in Bulletin 235, N. J. Experiment Station, p. 36, (1911), states the following concerning *E. rugulosus*: "It is an imported species and attacks almost all of our common orchard trees, boring into the bark to the bast and there making galleries in which the larvae develop. Perfectly healthy, vigorous trees are almost never attacked, and if entered by the beetle, the larvae do not find it possible to develop; but anything that serves to weaken or drain a tree, or make it temporarily less resistant, may serve to give these insects a foothold."

DISEASES RESEMBLING WORK OF FRUIT BARK BEETLE

We have already referred to the similarity between the symptoms of injury made by *E. rugulosus* and that inflicted by *Phloeotribus liminaris*; likewise, to the gumming caused by the presence of the peach boring moths, *Sanninoidea exitiosa* and *Sesia pictipes*; but, gumming may also be caused by the presence of bacterial diseases. One of these is called gummosis because of the excessive exudations of gum coming from infected pockets on the trunk. This disease is especially apt to accompany a hide-bound condition of the tree, following a severe infestation with San Jose scale. All of these manifestations of injury may be mistakenly attributed to the presence of *E. rugulosus*. The presence of shot-like holes in the bark, and of larvae beneath, and the form and position of the burrows will enable one to correctly separate an attack of the Fruit Bark Beetle from these other maladies.

HOST PLANTS

At Gypsum, Mr. King found the following plants harboring *E. rugulosus:* Cultivated plants; apple, pear, cherry and peach. Uncultivated plants; black cherry (*Prunus serotina*) and wild plum (*Prunus americana*). In addition to this list, Mr. Wilson recorded it at Lakeside on quince and plum among cultivated plants. From the quince a female beetle was taken, and in her burrow 23 eggs were found. European writers had previously recorded most of these hosts, all of the cultivated ones, and in addition thereto the apricot. Mr. F. H. Chittenden adds the nectarine in Cir. 29, Div. of Ent. U. S. D. A. Dobner records mountain ash as an European host, as does Eichoff hawthorn and elm.

PARASITES AND NATURAL ENEMIES

A hymenopterous parasite, *Chiropachys colon*, was quite common about the burrows of *E. rugulosus* in July, 1908. Tiny nematode worms were found by Mr. King as parasites in the bodies of the beetles. In form and color these were like the vinegar eel. *Anguillula aceti*, but smaller, ranging from .28-.44 mm. in length.

The various woodpeckers are voracious feeders upon the larvae, and badly infested trees are sometimes seen in the spring of the year with the bark practically all stripped away from the trunks and larger limbs, and hanging in loosened sheets and shreds over the bare wood—the result of winter work by these useful birds.

In Europe, two hymenopterous parasites, *Blacus fuscipes* and *Pteromalus bimaculatus* are effective agents in keeping the borer in check and deserve introduction into this country. The most common parasite which we already have, *Chiropachys colon*, is sometimes very prolific and effective. Dr. Chittenden notes that in one case, coming under observation at Washington, 92 parasites were reared from infested twigs against 72 beetles that escaped being parasitized. All but two of the parasites were *C. colon.* About one-half dozen other parasites have been reared from the larvae and a number of predaceous beetles have been recorded as probable enemies.* Up to the present time, none of these natural enemies, except the woodpeckers, have been noted as specially effective in Ohio, though *C. colon* was quite common in 1908, and it may have played a more important part than we discovered in reducing the beetle to comparatively unimportant numbers.

*Circular 29, Div. Ent., U. S. D. A., p, 6.

THE PEACH BARK BEETLE

Phloeotribus liminaris Harris.

HISTORY

This insect was early recognized as a peach pest, Miss H. H. Morris recording the belief in 1849 that it was the cause of peach yellows. The large number of beetles found on trees suffering with this malady constituted the basis of her opinion. Harris in his book on "Insects Injurious to Vegetation," published in 1852, writes as follows: "There is another small bark beetle, the *Tomicus liminaris* of my catalogue, which has been found in great numbers by Miss Morris under the bark of peach trees affected with the disease called "yellows" and, hence, supposed by her to be connected with this malady. I have found it under the bark of a diseased elm, but having nothing more to offer from my own observations concerning its history, except that it completes its transformation in August and September. It is of dark-brown color, the thorax all punctured, and the wing covers are marked with deeply punctured furrows and are beset with short hairs. It does not average one-tenth of an inch in length."

The elm beetle which Mr. Harris supposed to be *Phloeotribus liminaris* has since been proved to have been a different species. Occasional references to the Peach Bark Beetle are scattered through entomological literature between 1852 and 1902, some of these clearly indicating that the serious nature of the pest was recognized by more than one observer. Thus, Prof. C. V. Riley, writing in the Rural New Yorker Dec. 24, 1881, speaks of the "Beetle which is doing such injury to peach trees," further referring to it as an "Old acquaintance long known to injuriously affect peach trees." W. L. Deveraux, in the same issue of the same paper, says: "This beetle is a much more serious pest than any of the other injurious insects attacking and burrowing in the trunk and branches of the peach tree." In the Rural New Yorker of May 19, 1883, W. L. Deveraux writes: "This pest which works so much damage to peach trees," etc. Prof. J. A. Lintner writes as follows in Country Gentleman, July 9, 1885: "The injuries from *P. liminaris* seem to be rapidly increasing. They have been quite destructive for two or three years past at Bethlehem Center in the vicinity of Albany, and what is believed to be the same insect has killed many hundreds of young peach trees at Keuka, Steuben Co., N. Y., the last year." The same entomologist says in the Ninth Report of the State Entomologist of N. Y., in 1892: "If this little beetle once takes possession of a tree, unless it should be found that it can be effectually killed by kerosene as suggested (applied with an atomizer), the fate

of the tree is sealed and it cannot long survive." Prof. M. V. Slingerland in the Rural New Yorker, Oct. 21, 1893, says: "Where the beetles occur in large numbers the tree soon shows the effect of their attack. They are present in alarming numbers in many orchards in N. Y. State and Canada." Dr. James Fletcher in the Twenty-sixth Report of the Entomological Society of Ontario, 1895, speaks of the "Peach Bark Borer (*Phloeotribus liminaris*) which has for some years done so much harm in the peach orchards of the Niagara peninsula." In the transactions of the Royal Society of Canada, Vol. V, Sec. IV, 1899, the same author observes: "One of the most serious enemies of the peach grower in the Niagara peninsula, although frequently overlooked, is this minute Scolytid, which, although one-twelfth of an inch in length, by reason of its attacks and those of its larvae, causes such an enormously disproportionate outflow of gum from the trees that they are soon weakened and killed." In 1909, Mr. H. F. Wilson published as Part IX, of Bulletin No. 68, Bureau of Entomology, U. S. D. A., a comparatively full account of its life history and economy, based upon his observations in the Lake region of northern Ohio. It has been recorded from Michigan and probably ranges farther west than is known. It is at present recorded from New York, Pennsylvania, New Jersey, Ohio, Maryland, Virginia, West Virginia, Michigan, Niagara district of Ontario province, Canada, North Carolina and New Hampshire. Mr. Chas. Dury, of Cincinnati, gives Tyngsboro, Mass., as an additional locality, and has a pair collected by himself at Brownsville, Texas, which he "believes to be this species or very close to it." While Entomologist of the Ohio Station, Prof. F. M. Webster, under date of Dec. 31, 1901, makes the following statement in a letter to Mr. Geo. E. Fisher, Freeman, Canada, who had sent specimens of the beetles and samples of their work for identification: "I have only found it, (*Phloeotribus liminaris*), in Arkansas and once or twice in Ohio." Prof. J. M. Swaine says the species continues to be common and injurious in southern Ontario, and is also very common in southern Quebec on wild cherry, but he has never found it in Quebec orchards.

Its most serious injuries have been wrought in Ohio, New York and Ontario. Its devastations have been practically confined to peach, cherry and wild cherry.

OCCURRENCE IN OHIO

The Peach Bark Beetle is a native American insect and before the introduction into this country from Europe of the cultivated varieties of cherries and of peaches, it probably confined its attention to our wild choke and bird cherries, or their near relatives, such as

wild plums. It may have always existed in Ohio and adjoining states, such as West Virginia, where it is known to be widely and quite evenly distributed, but only in recent years has it attracted special attention in our state as a fruit pest. The concentration of peach orchards along the Lake Shore and the unhealthy conditions which have developed in many of these from the work of San Jose scale, other peach pests, and from the neglect of their owners, have produced an environment very favorable to the excessive multiplication of this species. It has been present in injurious numbers over a territory of something like 100 square miles, or most of the Marblehead peninsula and the adjacent islands for the past seven years, and was likely responsible for much of the damage in the same region, which, in the years immediately preceding, was credited to the Fruit Bark Beetle, *Eccoptogaster rugulosus*. Since both insects were generally at work in the same orchards, and frequently upon the same trees, this confusion was very natural and only an expert examination would be likely to discover the presence of both insects. In July, 1907, Mr. W. H. Wright, of Lakeside, called the attention of the writer to his orchard which was suffering greatly from an attack of bark beetles. At the time of the examination, only *Eccoptogaster rugulosus* was noticed, this being the proper time for the culmination of the summer brood of this species, and it was not until Mr. Wilson took up a minute investigation of the insects at work that the presence of *Phloeotribus liminaris* was discovered.

Wherever the orchard owners, generally, have whitewashed or otherwise treated their orchards, and have promptly burned all trimmings and dead wood, there has been considerable abatement of injury. Since these practices became quite general, at least for two or three seasons, the benefits have been quite discernible throughout the whole of the infested district.

Mr. Dury says of its distribution around Cincinnati: "I have never found it very abundant here and I have been collecting in southwestern Ohio for over 40 years." Mr. Wilson, in the publication previously referred to,* speaks of its having been captured at Youngtown, the statement probably being founded on records in the U. S. Bureau of Entomology. A specimen in the collection of the Ohio State University is labeled "Columbus, O., April 20, 1896." We have no knowledge of this species ever having done serious injury in any other locality in Ohio than in the beforementioned Lake district.

*Bulletin No. 68, Part IX, Bureau of Entomology, U. S. D. A.

Plate VII. Exit holes and gumming caused by the Peach Bark Beetle, *Phloeotribus liminaris*. Photo. by H. F. Wilson (Bul. Bur. Ent. U. S. D. A. No. 68, Part IX.)

SYMTOMS OF INJURY

The general symptoms of injury by this species are so like those which accompany the presence of the Fruit Bark Beetle, *Eccoptogaster rugulosus*, that a casual examination of its work is almost certain to lead the observer to attribute the damage to the more common insect. The trees gum copiously, the bark of the trunks and larger limbs being perforated with minute holes resembling the punctures made by fine bird shot, and the inner bark and cambium wood are channeled through in various directions and destroyed. As much as three or four gallons of sap may exude from a single tree of ordinary size in one season. A wild cherry tree, 75 feet or more tall and about 14 inches in diameter, on the Marblehead peninsula, was apparently killed by these beetles alone. If it was assisted by the Fruit Bark Beetle, the work of the latter was undiscoverable. All the bark from this very large tree was completely devoured by the insects. Trees that generally pass without question as healthy are attacked by the beetles for the purpose of feeding, but such trees are not selected for incubation. As winter approaches, the beetles burrow into the bark of healthy trees and construct cells in which to hibernate; a certain amount of gum will exude from each of these holes the next season and, in the spring, when the insects emerge from their winter chambers, they burrow from a quarter to one-half inch in the bark of the same or of nearby healthy trees, and the exudation from these added to that coming from the hibernation burrows, weakens the tree to a considerable extent; and when the attacks are renewed, as is apt to be the case later in the season, and also from year to year, the trees quite soon, almost certainly in three or four years, reach that sickly condition which best fits them to be rearing grounds for the young larvae. Egg burrows and larvae tunnels are then made and the larvae quickly complete the destruction commenced by adults.

DESCRIPTION

Egg: Milky white when first deposited, elliptical in shape, opaque and measuring on the average .44 to .47 mm. or about 1-50 of an inch long and a little more than two-thirds as much through the middle diameter (.36 to .39 mm. as an average, —approximately 1-75 inch). The egg shells are sufficiently tough to easily admit of the removal of the eggs from the burrows without breaking them. They can be more certainly preserved and handled by being boiled for a few moments in water.

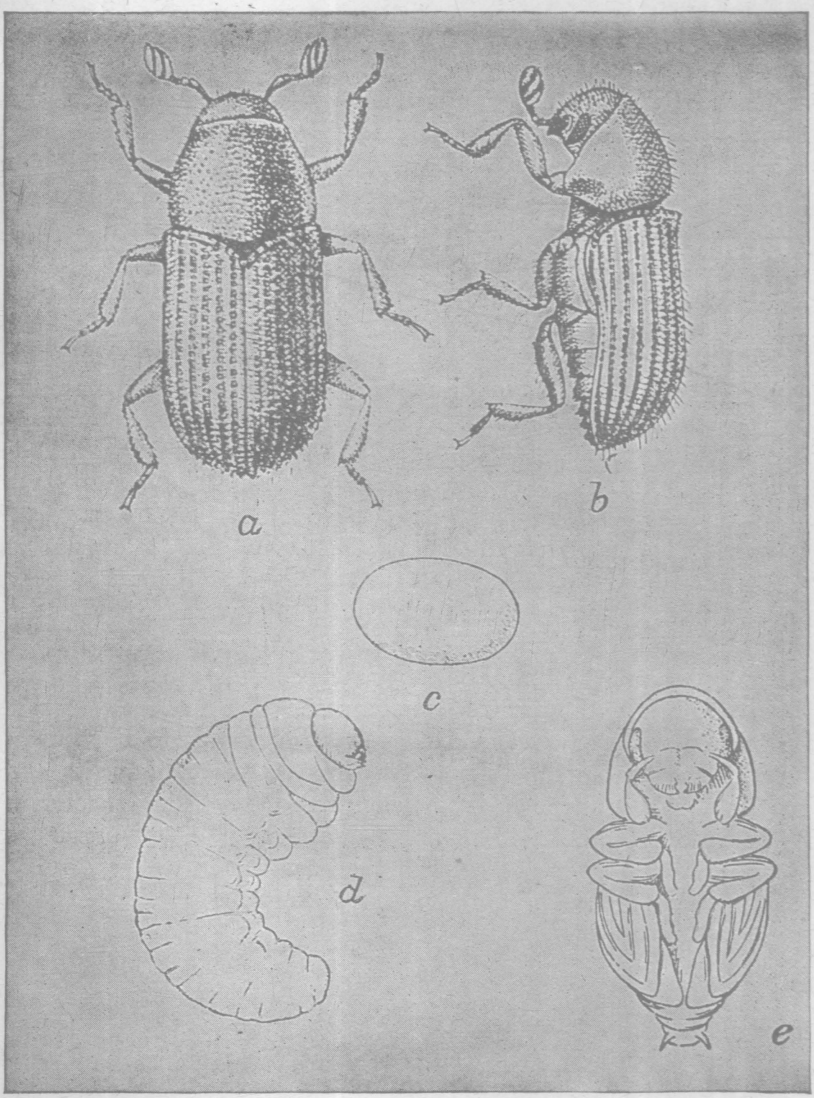


Plate VIII. Much enlarged figures of stages of Peach Bark Beetle, *Phloeotribus liminaris*: a and b, adult beetle; c, egg; d, larva; e, pupa. After Bur. Ent. U. S. D. A., Bul. No. 68, Part IX.

Larva: The new-born larva is a little longer than the egg and slightly more slender. The color is white but soon becomes pinkish, owing to the contents of the digestive tract. When full grown, about 25 to 30 days after hatching, they void their excrement, become clear white and pupate. They are then from 2.75mm. to 3mm. long. The head is covered over with fine, yellowish hairs at all times, these being most abundant about the mouth. Therefore, the head is always yellowish in color; the jaws or mandibles are brownish with dark tips. The body is curved, tapers somewhat toward the rounded posterior end and is quite wrinkled. Small groups of bristles occupy the places where legs are commonly found in this order. Many minute, short spines are distributed all over the body.

Pupa: Length 2.5 to 2.66 mm.; width 1.08 to 1.11 mm. Body white, showing a suggestion of yellow on the sides of the abdomen. Eyes, reddish brown; interior mouth parts, faintly brownish. Two whitish, brown-tipped horns terminate the abdomen, one on each side.

Adult: Average length 0.0885 inch or 2.25 to 2.5mm. and average width about .03 inch or .75 mm. The body is elongate, strongly punctured and has yellowish hairs arising from the punctures. The color varies from light brown to almost black. The underside of the abdomen is gradually concave and in strong contrast to the angle on the abdomen of *Eccoptogaster rugulosus*, where the posterior segments are reflexed suddenly backward and upward from the more forward ones. The wing covers are deeply margined, sides parallel, surface with regular grooves in which are ranged numerous circular pits, the elevated parts with yellowish hairs arising from faint punctures.

The following technical description by Mr. Wilson is appended for the use of Entomologists:*

"Average length, 2.25 mm., average width, 0.75 mm. Body elongate, subcylindrical, strongly punctured and with yellowish bristles arising from the punctures; color varying from light brown to almost black. Head globular, nearly vertical in front, anterior part fringed; eyes narrowly oblong, closely joined to the scape and extending about half their length below it; mandibles short and broad, distal part curved and strongly acute; mouth parts partly inclosed, gular suture distinct; funiculus of antennae five-jointed; club compressed, composed of 3 triangular segments; first joint longer than wide, globular; scape circular, clavate. Thorax almost cylindrical, strongly angled at caudal end. First and second coxae widely separated, globular; femur stout, outer edge serrated; tibia, third joint bilobed, fourth indistinct, fifth as long as first and second together, tarsal claws simple. Ventral side of abdomen and posterior edge of last segment strongly concave; elytra anteriorly rounded and deeply margined, sides parallel, surface with regular striae which contain circular, regularly placed depressions, elevated parts with yellowish bristles arising from faint punctures."

*Bulletin 68, Part 9, Bureau of Entomology, U. S. D. A.

LIFE HISTORY AND HABITS

In northern Ohio the hibernating beetles commence cutting their way out from their winter cells with the first warm days of spring, sometimes in late March, but it is generally later than this before the majority of them become active. About the middle of April or a little later, under average conditions, they may be seen issuing in numbers from their burrows and crawling about over the trees. In 1908, activity was observed April 8 in orchards near Lakeside. A beetle, here and there, could be found on the bark, and openings had been quite generally made from the pupal cells to the outside. The beetles would move about somewhat sluggishly when cut out from their burrows, notwithstanding the chilly temperature. April 16, 1912, they were working in peach and cherry at Gypsum, the brownish frass at the mouths of their burrows indicating their whereabouts, and also that they had been feeding for a few days. The interval between their resumption of activity and their appearance outside their burrows, usually of three or four days to a week or longer, is spent in feeding.

Both dead and living wood is used for hibernating cells, and when they leave their winter shelters, they go to either dead or living trees, to wood piles, to brush heaps, or to any wood in which they can feed and rear their young. Migration from tree to tree is usually accomplished in the afternoon, but little flight being indulged in during the morning hours and practically none at night. During the daylight hours, the females seek suitable situations for starting burrows, while the males seek the burrows of females not yet appropriated by males. Flight and movements over the tree cease when nightfall is well settled, though flight seems to be most active just at the twilight hour. Migrational activity apparently commences about the middle of the afternoon.

The burrows of this insect are characteristic and readily distinguishable from those of *Eccoptogaster rugulosus* and other common shot-hole or pin-hole beetles. The entrance to the burrow is partially closed by a gummy exudate, mixed with bits of bark-dust and frass, the mass being bound together with a fine silken thread which is manufactured by both sexes. This mass, partially covering and extending somewhat into the burrow, is not found at the entrance to the burrows of *E. rugulosus*. The female commences burrowing into the bark, nearly always entering at a lenticel, and if the sap in the tree proves scanty, she constructs the brood chamber just between the sapwood and the bark; if, however, the sap is abundant, the galleries are confined to the bark, though sometimes impinging on the sapwood. The main chamber of the burrow may

be anywhere from 1 inch to 2.625 inches long, the average length being about 2.06 inches. The diameter of the main burrow varies between 1-8 inch or less to 3-16 of an inch or thereabouts. It is nearly always formed transversely across the trunk or limb, but is occasionally inclined at an angle of 45 degrees or less to the axis of trunk or branch. Since the main burrows of *E. rugulosus* are more often than not vertical, or nearly so, there need not be much doubt as to which species formed any particular burrow. A fork is formed well toward the inner end of the burrow, commencing at the point where the burrow first touches the sapwood. When the point is struck, the female forms a little niche at an angle to the part already excavated, and she then begins excavating in the opposite direction, thus making another and approximately equal angle with the main burrow. While this opposite extension is being made, the male copulates with the female at the fork. When in copula, the female occupies one arm of the fork, head inward, the point of her abdomen just at the fork, while the male operates from the other arm. At other times, the male may be found almost anywhere in the burrow, between his special niche and the burrow's mouth. Only a single pair are to be found in a burrow. Copulation occurs an indefinite number of times, and has been observed on several

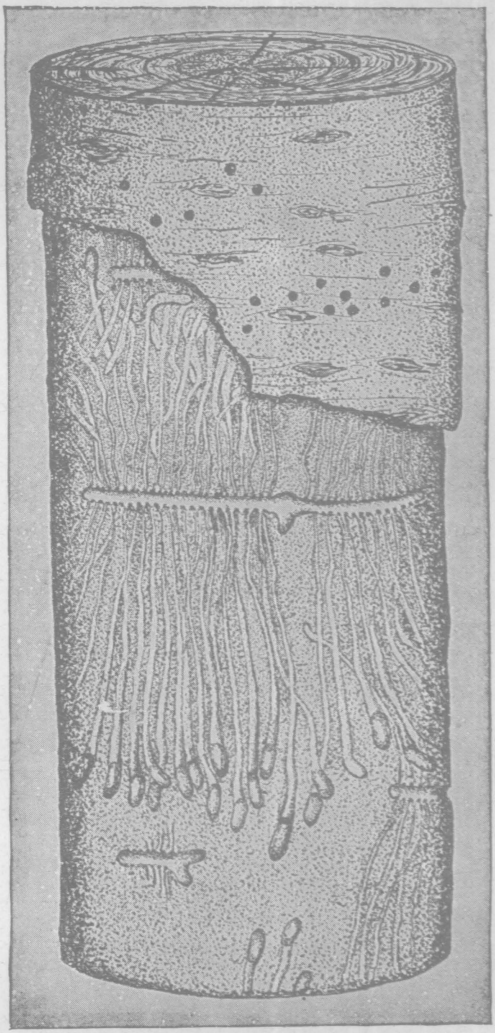


Fig. 7. Brood chamber and galleries of *P. liminaris*.

occasions to continue for 15 minutes and longer after the burrow was cut open. The two forks of the chamber may differ considerably in length. The time consumed in constructing the brood chamber may vary from 10 days to 3 weeks and possibly, under unusual conditions, the period has yet wider limits in both directions. After entering their brood chamber, the male and female of each pair seem to remain there until they die; they may sometimes be found in their burrows, feeble and sluggish, after some of their offspring have reached the beetle stage.

Along the sides of her burrow, the female excavates little niches which may be very close together or considerably separated. These cells are for the reception of eggs, one egg being deposited in each cavity. The eggs are not ranged in straight lines along the sides of the chamber, but may zigzag a good deal. The distance between the eggs is somewhat variable; two may be touching, while others are separated by an interval. However, since the egg-cells are generally located where the bark and the sapwood meet, there will always be two plainly discernible, though not very straight, egg-lines in each burrow. This arrangement holds good in those cases where the burrow is not made next to the sapwood, this sometimes occurring where the bark is very thick; in such a case the burrow is formed in the bark at a depth of about one-fourth inch. As soon as the female has excavated a cell, she backs out of the burrow to the fork, when she reverses her position, and backs into the burrow until she reaches the cell just made, in which she deposits an egg. She then crawls forward to the fork, again turns round and creeps into the brood arm, head foremost. She then proceeds to cover the egg, which stands on end in the cell, with a sawdust-like frass. These sawdust caps over the cells are confluent and form a tubular lining to the burrow, smooth within, and the eggs outside of it. Each egg-cell is filled with an egg as soon as completed, and a new one is excavated as soon as the burrow is extended far enough to make room for it. Deposition of eggs commences as soon as the female has been fertilized, which is generally within a week or so after activity has begun in spring. In 1908, copulation was observed April 24 and eggs were found May 2. In 1912, eggs were found May 5. The length of the egg-laying period is indefinite, seeming to depend on the number of copulations happening to the female, of which there may be several in each case. At the commencement of the egg-laying period the abdomen of the female is much distended. When working without interruption, a female will excavate from 2 to 10 cells per day and deposit an egg in each. A completed brood chamber may contain from 80 to 160 eggs.

In the territory studied, eggs can be found from about the 20th of April until October 1. The fully matured, curved embryo eats its way out through the shell wall at or just above the base of the egg and commences feeding on the under surface of the bark. In dimensions, the new-born larva is slightly longer and a little more slender than the egg. It rests for a short time lying in a slightly curved position in its burrow. The white color of the new larva is soon suffused with pinkish, owing to the bark particles in the digestive tract. Feeding is slow at first and the larvae are several days getting away from the egg-shell, but increase the rate of progress as they grow older. The excrement fills the egg-shells as the larvae gradually work out and away from them, thus permanently marking the location of the shell from which each larva issues. When the bark is removed, the course of the burrow is plainly marked by the line of brownish excrement which completely or partially fills its entire length.

The larvae excavate their galleries at right angles to the parent burrow, generally following the grain of the wood. For some distance out, the galleries lie side by side and parallel to each other, but at a distance of one-half to three-fourths of an inch from the parent burrow, they commence to diverge so that the terminal ends and, therefore, the exit holes form an irregular ellipse around the brood chamber. The length of the larval galleries is from 1.5 to 2.875 inches. The larvae require from 25 to 30 days to become grown, and, when fully matured, they burrow outward making a pupal cell just beneath the outer surface of the bark. They continue development for two or three days in their cells, then, having finished feeding, they void their excrement, becoming clear white instead of pinkish, cast their skins and become pupae.

The pupae are quite active, moving the abdomen continually back and forth. They gradually assume a dark color, and in from 4 to 10 days shed their skins, producing some very tender beetles. These beetles harden up within 4 to 6 days and feed from the walls of the pupal cell. When well hardened, and sometimes before, the beetles cut their way through the bark to the outside, but are not apt to leave the cells until a period of several days to two weeks or longer has elapsed.

NUMBER OF BROODS

There are two complete broods per year in northern Ohio, the summer brood appearing about July 20, reaching a maximum during the latter part of August and gradually dwindling to a few stragglers in late September and early October; and the fall or hibernating brood which yields adults in October and November.

From October until freezing weather, the fall adults are steadily emerging and migrating to growing trees. They enter such trees through rough places on the bark and excavate short burrows from one-fourth to one-half inch or more in length. These burrows are closed in their outer course by the exudation of gum and the beetles utilize the innermost ends as hibernation chambers. The latest formed or retarded adults hibernate in their pupal cells, not cutting their way out until the next spring. Hibernation, therefore, occurs in both living and dead wood, the emerged beetles making cells in the former, and the retarded beetles remaining in their pupal cells in the latter. There is a little overlapping of the summer and fall broods, so it seems there is no time in the year when at least a few beetles cannot be found, if infestation is general and severe. The very late beetles of the summer brood probably do not oviposit in the fall but hibernate with the fall beetles in living wood and reproduce in the spring. The spring brood is at its maximum in numbers and activity in late April and during the first two or three weeks of May, terminating almost wholly by early July, though an occasional specimen will linger until after the appearance of the summer brood in the latter part of the month.

The following table prepared by Mr. Wilson, shows the varying rate of emergence of the summer brood:

TABLE II. Emergence of summer brood of beetles of *Phloeotribus liminaris*

Date[1]	Beetles reared in cages	Beetles from insectary on window screens	Date	Beetles reared in cages	Beetles from insectary on window screens
July 16	2	60	August 25	40	.....
" 23	..	30	" 26	60	1,500
" 24	...	74	" 27	86	1,000
" 26	83	....	" 28	69	600
" 27	..	300	" 29	72	1,000
" 28	32	....	September 3	154	200
" 29	30	....	" 4	111	...
" 31	82	450	" 5	40	200
August 4	68	....	" 7	67	75
" 5	..	350	" 10	18	...
" 6	84	500	" 11	38	...
" 6	151	...	" 13	91	40
" 12	258	450	" 15	37	...
" 15	...	1 200	" 17	29	...
" 16	...	750	" 19	12	...
" 17	...	750	" 22	32	...
" 18	317	1 750	" 24	21	...
" 21[2]	327	2 500	" 29	7	...
" 24	129		October 2	4	...

[1] The first column shows beetles actually counted and taken from a breeding cage; the second row of figures shows, somewhat estimated, numbers of beetles gathered on screens at windows. All counts made between 4 and 6 p. m.

[2] This table shows August 21 to be the date of maximum emergence of beetles.

FOOD PLANTS

Mr. Wilson recorded peach, cherry, wild cherry, mountain ash and plum as host plants. He did not find it on plum in the field, but reared it on plum trimmings in a breeding cage, readily getting the

second generation in this manner. Mr. King recorded it from peach, cherry, wild cherry and wild plum growing in the field. Its preference seems to be for peach and cherry, next for wild cherry.

PARASITES

The only parasite found working on this species was a tiny nematode worm, located by Mr. King within the body cavity. The same or a very similar nematode was also found in the body of *E. rugulosus*. Efforts were made by Mr. Wilson to breed some of the parasites of *E. rugulosus* on *Phloeotribus liminaris*, but without success. Where the two beetles were found breeding in the same wood and the parasites of *E. rugulosus* were abundant, there was a corresponding diminution in the numbers of *E. rugulosus*, whereas, *P. liminaris* issued in numbers corresponding to the numbers of larval chambers. Mites, found in considerable numbers in the burrows and clinging to the hairs of the beetles, are apparently not parasites but feeders on the excrement and other decaying matter within the burrows. They attach themselves to the beetles in order to procure easy transportation from one place to another.

REMEDIES FOR BARK BEETLES

So similar are the habits, life-histories and economy of the two species of bark beetles, *E. rugulosus* and *P. liminaris* that the same measures of prevention and remedy apply to both, and efforts directed especially against one of them will be found to be almost equally effective against the other.

1. **Create an Unfavorable Environment for Propagation:** As indicated in the Introduction to this bulletin, old and neglected orchards that have died from the effects of San Jose scale attack, or which for any reason have become unprofitable and have been allowed to remain standing without care, furnish an ideal incubating ground for these beetles. Large areas on the Marblehead peninsula, adjacent to the villages of Marblehead, Lakeside and Gypsum, planted to peach orchard, are underlaid with valuable lime deposits, and much of this land was purchased a few years since by various syndicates. After these purchases, in some cases, especially where the orchards were infested with San Jose scale, they were totally neglected and allowed to die as fast as they would. These dead and dying trees, with just a little life in them, exactly supplied the conditions most favorable for the multiplication of both species of bark beetles. As a consequence, the insects were soon spread out over all the contiguous peach-growing country, and, when the supply of unhealthy trees was exhausted, they turned their attention to

some of those that were healthy, and by repeatedly attacking them, caused such losses of gum and sap that the trees gradually weakened, whole orchards of good trees being at times threatened with final destruction.

Trimmings and woodpiles constitute a similar source of danger. Many of the orchardists try to conserve the waste products of their farms and wish to utilize the trimmings from their peach trees, also dead trees, for stovewood. Such wood may be profitably burned during the winter months, but, if infested, should not be kept later than the middle of April when the adults of *P. liminaris* become active. If only *E. rugulosus* is present, the woodpile may be continued until the middle of May, but all infested wood, not used up in stoves by the dates specified, should be burned in the open to prevent the escape of any beetles to the orchard. Many cases are known of orchards becoming infested from woodpiles where peach wood was carried over from year to year. We have frequently found several rows of trees, adjacent to the woodpile, suffering greatly, the severity of the attack gradually diminishing as the distance between the woodpile and the trees increased. One of the peach growers in the Marblehead district attributed the commencement of the great outbreak of bark beetles in that territory, about 1906-07, to the use of peach brush as a barrier to protect the shore line near Ohlemacher' Landing against the wash of Lake Erie. The brush was piled in a long windrow along the shore, just south of the terminus of the Toledo, Port Clinton and Lakeside Trolley Line, to prevent the destruction by erosion of a peach orchard adjoining the shore. Several rows of trees in this orchard were killed by bark beetles the following summer, and within two or three years the whole orchard was practically dead. Dead peach wood seems to offer suitable conditions for developing brood as long as the bark adheres to the wood, provided sufficient moisture is present. Messrs. Wilson and Goodwin found piles of dead infested wood in June and July, 1908, well covered with grass of two seasons growth, and, therefore, readily holding considerable moisture. This wood was as full as it could well be of the larvae of both species of bark beetles, thus proving that they breed readily in wood that has been dead and piled on the ground for considerably over a year.

It is obvious that all orchard trees should be regularly trimmed each year, and all dead and sickly limbs, branches and stubs cut away and burned. Very weak trees, as well as dead ones, should be removed and burned. Trees dying late in the summer may be left as traps and cut late in the fall when full of larvae. Trees dying in the spring should either be burned at once or else left as

traps until filled with larvae, when they should be consumed; also, dying trees, of varieties susceptible to infestation, in nearby woodlots, should be cut down and burned. If whole neighborhoods would cooperate together in these clean culture measures, never through neglect omitting any of them, a general outbreak of these beetles, or even notable damage by them, would be very improbable, in fact, almost impossible.

2. **Cultivation and Fertilization:** Since both of these measures stimulate growth and increase the sap flow, both help the trees to maintain a condition that is unfavorable to production of bark beetle brood, and the wounds made in such trees by the adults to feed are more quickly repaired than is the case with uncultivated and starved trees, when attacked. An abundance of barnyard manure is generally the best fertilizer. However, we have used some combinations of mineral fertilizer on our experimental blocks and have found that they possess some value. On poor land, they would doubtless have proved of much greater help.

3. **Whitewashing and Similar Treatments as Preventives of Attack:** Whitewashing has proved of much value in preventing attack, but under some circumstances its effectiveness is much diminished. We have never known of trees in good general health that did not successfully throw off an attack, if carefully whitewashed two or three times per season through a period of two or three years. Old and decrepit orchards can generally be rejuvenated if severely headed back to stubs, cultivated, and fertilized, and then regularly whitewashed for a few years. If there is a nearby exhaustless breeding ground for bark beetles, this treatment may not avail. Thus, we have sometimes had blocks of trees so circumstanced that they continued to suffer and be reinfested with brood, notwithstanding a heavy coat of whitewash. Whitewash does not interfere in any way with larvae already beneath the bark, but fills up rough places in the bark, thus making it difficult for the females to satisfactorily place their eggs. Also, these beetles, in common with most insects, dislike to expose themselves on a white surface. Whitewash may be made thin enough to apply with a spray pump, but it requires two or three successive applications, a day or so apart, to get a really protective coating. About 4 pounds of table salt to each 50 gallons of spray increases the sticking qualities. Most of our applications consisted of a thick whitewash, with one-fourth pound of salt to each 3 gallons, and these were made with a broom to the trunks and the larger branches. If the beetles are excessively numerous in the neighborhood, make three applications during the season, the first by or before April 1st, the second about the middle of July, and the third by or a little before October 1st.

Of the other washes tried, Carbolineum Avenarius has been the most successful. Used in concentrated form this material is too expensive for use, and is dangerous to the life of even healthy trees. We have seen several trees that were killed outright by being painted with the undiluted material during the dormant winter period. In other cases, trees have survived the same treatment under apparently the same conditions without perceptible harm.

Mr. Wilson found, in some instances, that the larvae in their burrows had been killed where a coating of Carbolineum or of Carbolineum emulsion had been given the bark, while the trees seemed uninjured. Since no observers have since been able to confirm this conclusion, and several have had equally good opportunities to see effects, we believe that results are variable with this mateirial, or else, less probably, that something besides the Carbolineum must have caused the death of the larvae examined by Mr. Wilson. Emulsions of Carbolineum have apparently been somewhat more effective than whitewash for repelling the insects, and in case of severe attack, the extra cost seems to us to be warranted by the results, especially where valuable trees are endangered. The most successful formula we have used for making an emulsion is as follows:

Dissolve 4 pounds of of naptha soap in 4 gallons of water and, while this is boiling hot, remove from the fire and add one gallon of Carbolineum Avenarius, agitating with a force pump, or for small quantities with a rotary egg-beater, exactly as if preparing kerosene emulsion. When well emulsified, add 3 gallons of hot water and apply to the trees while warm. Keep face and hands well protected and horses well blanketed when applying this emulsion, and work only on the windward side of the trees, as it is very penetrating and is likely to cause blistering and sloughing off of the skin, should this become wetted with it. These emulsions of Carbolineum seem not to have injured the trees in any case.

EXPERIMENTAL DATA SUPPORTING CONCLUSIONS AS STATED

The full program of 43 plot tests conducted by Mr. Wilson in 1908 is shown herewith, the number of trees used in each plot being mentioned in connection with each treatment:*

1—Used 16 trees. One part by weight of lime; 2 parts by weight cement; milk used to make a stiff whitewash and applied with a broom to 96 trees, 32 of which were used in experiment No. 2, with the addition of manure. Thirty-two more were used for experiment No. 3, with an application of commercial fertilizer. Sixteen trees of each plat were given a second application, forming experiments Nos. 4, 5 and 6.

*Bull. 68, Pt. IX, Bureau Ent., U. S. D. A.

Date of application, April 9, 1908.

2—Used 32 trees of experiment 1. Barnyard manure spread in a 7-foot circle about each tree, to get value of fertilizers.

Date of application, April 9, 1908.

3—Used 32 trees of experiment 1. Commercial fertilizer applied in a 7-foot circle about each tree.

Cement applied April 9, 1908; fertilizer applied May 7, 1908.

4—Used 16 trees of experiment 1, making a second application.

First application, April 9, 1908; second application, July 3, 1908

5—Used 16 trees of experiment 2, making a second application

First application, April 9, 1908; second application, July 7, 1908.

6—Used 16 trees of experiment 3, making a second application.

First application, cement, April 9, 1908; fertilizer, May 7, 1908; second application, July 3, 1908.

7—Used 2 pounds fish-oil soap per gallon of water (dissolving soap in boiling water) for first application. Used 1 pound of soap to 6 gallons of water for second treatment. Twenty-four trees treated, 16 to be used for experiments 8 and 9.

First application, April 10, 1908; second application, July 7, 1908.

8—To each of 8 of the 24 trees treated in experiment 7 added barnyard manure to find value of fertilizers.

First application, April 10, 1908; second application, July 7, 1908.

9—To remaining 8 trees of experiment 7 added commercial fertilizer, 4 pounds to each tree, spreading in a 7-foot circle.

Fertilizer added May 7, 1908; second application, July 7, 1908.

10—One gallon Carbolineum mixed with 20 pounds of flour, then 25 gallons water added to make emulsion; sprayed 72 trees, 48 of which were used for experiments 11 and 12 to get value of fertilizers.

Sprayed whole tree April 10, 1908; sprayed trunks and limbs below foliage July 6, 1908.

11—Used 24 trees of experiment 10, and added barnyard manure, spreading in about tree in 7-foot circle.

First application, April 10, 1908; second application, July 7, 1908.

12—Used 24 trees of experiment 10, and added 4 pounds of commercial fertilizer to each tree, spreading it in 7-foot circle about tree and harrowing in.

First application, April 10, 1908, second application (3 pounds commercial fertilizer) July 6, 1908.

13—Used 1 gallon Carbolineum, emulsifying it with 4 pounds soap (dissolved in 4 gallons of water) and diluting the whole to 8 gallons; sprayed 144 trees, 96 of these to be used in four more experiments.

Application made April 10, 1908.

14—Used 48 trees of plat 13. Sprayed twice.

First application, April 10, 1908; second application, July 6, 1908

15—This was to have been a third spraying, but was found unnecessary on account of absence of beetles.

16—Used 24 trees of experiment 13. Barnyard manure (to get value of fertilizers) spread about trees in a 7-foot circle.

First application, April 10, 1908; second application, July 6, 1908

17—Used 24 trees of experiment 13. Commercial fertilizer added 4 pounds to each tree, spread in a 7-foot circle to get value of fertilizer.

First application, July 3, 1908, (3 pounds fertilizer).

18—Sprayed 6 trees with pure Carbolineum without seeming injury to the trees.

Application made April 9, 1908.

19—Used 25 pounds of lime, 15 pounds sulfur, 6 pounds resin, 3 pounds arsenate of lead, and 50 gallons of water. Applied the mixture with a brush to trunks and large limbs of 6 trees.

Application made April 17, 1908.

20—Same as experiment 19, plus barnyard manure. Two of 6 trees in experiment 19 used.

Application made April 17, 1908.

21—Same as experiment 19, plus commercial fertilizer. Two of 6 trees in experiment 19 used.

Application made April 17, 1908.

22—One gallon Carbolineum, 1 gallon lard and 25 pounds resin. Painted trunks and larger limbs of 5 trees.

Application made April 17, 1908.

33—One bushel tobacco stems boiled for one hour in 4 gallons of water; one-half bushel stone lime and 4 quarts salt added; one-half pint crude carbolic acid used in each 12 quarts of the liquid. All gum and rough bark scraped from the trees and the paint put on with a broom.

Applied the mixture of 72 trees April 22, 1908.

24—Used 24 trees of experiment 23. Same treatment, plus barnyard manure spread in 7-foot circle about each tree.

Application made April 22, 1908.

25—Used 24 trees of experiment 23, plus commercial fertilizer spread in 7-foot circle about each tree.

Applied April 22, 1908; fertilizer applied May 7, 1908.

26—One gallon Chloronaptholeum, emulsified with 4 pounds of soap (dissolved in 4 gallons of water); then added water enough to dilute 25 gallons. Sprayed 120 trees.

First application, April 22, 1908; second application, July 7, 1908.

27—Used 24 trees of experiment 26; added barnyard manure, spreading it in a 7-foot circle about each tree.

First application, April 25, 1908; second application, July 7, 1908.

28—Used 24 trees of experiment 26, adding commercial fertilizer, 4 pounds to each tree, spreading it in a 7-foot circle.

First application, April 22, 1908; fertilizer added May 7, 1908; second application, July 7, 1908 (3 pounds fertilizer added).

29—One gallon Chloronaptholeum mixed with 22 pounds flour to emulsify, added to 30 gallons water, and put on 120 trees with spray pump.

First application, April 17, 1908; second application, July 13, 1908.

30—Used 24 trees of experiment 29; added barnyard manure to get value of fertilizer.

First application, April 17, 1908; second application, July 13, 1908.

31—Used 24 trees of experiment 29, adding commercial fertilizer, 4 pounds to each tree.

First application, April, 17, 1908; fertilizer added May 7, 1908; second application, July 13, 1908.

32—Six pounds arsenate of lead to 50 gallons water; 3 pounds lime added to neutralize the free arsenic. Put on heavy spray; pruned trees before spraying; 170 trees sprayed.

First application, April 20, 1908; second application, July 13, 1908.

33—Boiled lime and sulfur spray (15 pounds lime, 15 pounds sulfur, 50 gallons water.) Excessive application made to 200 trees.

First application, April 24, 1908; second application, July 13, 1908.

34—Self-boiled lime-sulfur wash (15 pounds lime, 10 pounds sulfur, 50 gallons water). Water added slowly so as to prevent burning, stirring vigorously during the process. Sprayed 300 trees.

First application, May 18, 1908; second application, July 13, 1908; to trunks and larger limbs.

35—A stock solution of kerosene emulsion, 20 percent strength, was made and to each gallon of stock solution 2½ gallons rain water were added. Applied with spray pump.

Application made April 20, 1908.

36—Fumigated 6 trees with hydrocyanic-acid gas for one hour, first scraping off all gum and rough bark. Treatment given August 24, 1908.

37—Tree tanglefoot. Put bands around 12 trees and then covered bands with tanglefoot. Application made April 25, 1908.

38—Renovation block. Pruned back severely about 100 trees (girdling 4 trees for traps and not treating them further); applied fertilizer twice and kept trees cultivated all summer.

Plate IX. Photograph in Experimental Orchard; whitewashed blocks and others treated with Carbolineum emulsion. *Photo. by L. L. Scott*

First application, April 19, 1908; fertilizer added May 7, 1908 (4 pounds per tree). Second application, July 3, 1908 (3 pounds fertilizer added).

39—A duplicate of experiment 17 tried on 200 trees; pure whitewash was applied as a second treatment.

Emulsion applied April 21, 1908; whitewash applied September 1, 1908.

40—Placed pieces of branches as traps in trees of small orchard to see if beetles would settle on them.

41—One-half barrel kerosene emulsion used instead of water to make a good, stiff whitewash, applying with broom to plat of 200 or 300 trees.

First application made May 4, 1908; second application, July 9, 1908.

42—One gallon of Chloronaptholeum added to every barrel of whitewash used. Whitewash made as thick as possible and applied with a broom to plat of about 200 trees.

First application, May 6, 1908; second application, July 9, 1908.

43—One gallon of Avenarius Carbolineum added to each barrel of whitewash used; whitewash made as thick as possible and applied with a broom to a plat of about 200 trees.

All fertilizer used in above experiments was of the following formula:

Phosphoric acid	8 percent
Nitrogen	5 "
Potash	2 "

All trees fertilized made a growth of rich green foliage and the trees looked healthy, yet many of them were again attacked by the beetles.

Mr. Wilson summed up the results of this set of experiments as follows:

"The first 6 experiments seem to show that whitewash acts as a repellent, not affecting the beetles once they are in the bark, but if the trees are kept well coated the beetles do not seem to attack the whitewashed parts. The addition of fertilizer to the trees causes a strong flow of sap which, exuding through the burrows, seems to repel the beetles. The treatments given in Nos. 7, 8 and 9 seemed to have no effect whatever. In experiments 10, 11 and 12 the beetles in the tree at the time of application appeared to be killed, but the mixture did not act as a repellent and beetles settled on the trees again in a short while. Experiments 13, 14, 15, 16 and 17 were more promising, and two applications a season would undoubtedly keep the beetles down. The expense of these

experiments, however, makes them impracticable as tried here. In experiment No. 18 all beetles attacking the trees at the time of application were killed, and others did not settle on the trees during the entire season.

The cost of materials used in this experiment, however, makes the treatment impracticable. Experiments 19, 20 and 21 had no effect whatever, neither killing the beetles in the trees nor repelling others. In experiment 22, all trees treated were killed. Experiments 23, 24 and 25 gave very good results, the whitewash sticking well and the beetles not attacking the trees until long after the whitewash had fallen off. Experiments 26, 27 and 28 seemed to have had very little effect on the beetles in the bark and did not repel later attacks. Experiments 29, 30 and 31 failed to give any beneficial results, the emulsion being very poor, as the oil became partly separated from the mixture before the latter could be applied. Experiments 32, 33, 34, 35, 36 and 37 gave only negative results, neither killing the beetles in the burrows nor repelling later attacks. In experiment 38 a plat of 100 trees was used. Fifty of the trees were very severely cut back and 4 or 5 of them, being too weak to recover, died. The other 50 trees were sprayed with lime-sulfur wash. At the end of the season the pruned trees had produced a strong, healthy foliage and the beetles were attacking them but little. The untrimmed trees were badly attacked and had thrown out a scant, sickly-looking foliage. Experiment 39 gave satisfactory results. All of the beetles in the trees at the time of application were killed and no more settled on them until about the last of September; then a few having settled, the trees were whitewashed and further injury was stopped. The cost of this treatment, as made here, prevents it being practicable for a large orchard unless the amount of material used can be reduced with equally good results for the weaker emulsion. Experiment 40 showed that the beetles attack the trees in which these cut branches were placed without settling on the cut branches. Experiments 41, 42 and 43 showed the most practicable, and at this time the most likely remedies. These are the combinations of a whitewash and an oil, the whitewash probably being the main factor in repelling the beetles. The cost of these experiments was 1¼ cent per tree for each application. The trees in these plats, while not entirely free from further attack during the season, suffered considerably less than surrounding plats of trees."

The following year Mr. L. L. Scott made applications on a much larger scale of those remedies which Mr. Wilson had found most promising. The general plan of experimentation in 1909 was as follows:

LARGE SCALE EXPERIMENT

1—Cut back a badly infested block of trees to stubs of main limbs, fertilize and whitewash.

2—Fertilize and whitewash a slightly infested block.

SPECIAL TREATMENTS FOR BADLY INFESTED BLOCKS

3—Cut back to stubs.

4—Cut back to stubs and fertilize.

5—Fertilize, with ordinary sort of trimming.

6—Same as 4 with whitewash added.

7—Trim in ordinary way and whitewash.

8—Cut back and whitewash.

9—Spray with 12 percent Carbolineum emulsion, and trim in ordinary way.

10—Same as 9, but cut back to stubs.

11—Same as 9, but cut back and fertilize.

12—Check.

Each block used in these experiments approximated one-half acre or more of trees. Mr. Scott summed up the results of his season's work as follows:*

"A large number of remedies were tried during the season of 1908 and during the past season only those were tried which gave best results the previous year. Among these, several seemed to give about equally good results; but one appeared to do a little better than the rest, and it may be well to present that here.

Two blocks of Elberta trees were selected and on one an application of a seven percent soap emulsion of Carbolineum Avenarius was made, and on the other a twelve percent emulsion was applied, and since both of these blocks grew so well, had such thrifty green foliage and seemed so free from beetle attack, it appeared that these emulsions were about the best remedies tried.

Carbolineum is a wood preservative and is corrosive to the flesh, so naturally can not be applied when trees are in foliage else the leaves will all be burned, so that the applications necessarily have to be made when the trees are still dormant, or at least before the leaves open in the spring, and then the spray should only be directed against the trunk and bases of the larger limbs of the tree, or there may be danger in injuring some of the unopened buds. A Bordeaux nozzle may be used, and was quite satisfactory if held with the spread of the spray parallel to the trunk and limbs. As a further remedy, it is well to follow the practice of many and whitewash the trees a little later in the spring, and again in the late summer, if there is

*Forty-third Annual Report, Ohio State Horticultural Society, January, 1910.

time; the whitewash not only acts as a preventive against the beetle but it also serves to keep the bark of the tree smooth, and in addition it gives the orchard a nice, clean appearance, which is a point worth considering by any grower.

If trees are so badly infested by the beetle that they cannot be saved in any way, they should be dug out during the winter and burned immediately, as in this way thousands of hibernating larvae will be destroyed, which would cause a more serious infestation the following year if the brush were allowed to lie around unburned.

Where trees are quite badly infested, but there is a possibility of saving them, cut out all infested parts and severely head back the entire tree; then fertilize well with some good, complete commercial brand, and give the tree thorough cultivation in order to stimulate as healthy a growth as possible, so the tree may recover from the attack.

Finally, with healthy trees to begin with, give them all the care and attention they demand, feed them, care for them as you would expect to for any other living thing on the place, and it is altogether probable that an attack will be postponed if not entirely averted."

In 1907, a vigorous young peach orchard of about 100 trees at Longley, Ohio, was severely attacked by *S. rugulosus*. An old apple orchard nearby had been killed by scale and the trees had been gradually cut down and the wood kept for stovewood. The beetles started with these conditions and bred rapidly. The peach orchard had never been very scaly and was sprayed regularly with lime-sulfur wash. Notwithstanding the general good health of the trees a few had died from repeated attacks by the beetles and many were gumming badly. By advice of the writer, the owner of the orchard painted the trunks and larger limbs with a stiff paint made by mixing together Portland cement and water. By the spring of 1908, the condition of the trees was greatly improved.

April 10, 1908, one-half of the orchard was painted with water-cement, and of the remaining half, one tree was painted with pure Carbolineum, 5 others were painted with almost pure Carbolineum which separated from and floated on the top of an imperfect emulsion, while the remainder were sprayed by means of a hand pump with a 12½ percent good and stable emulsion of Carbolineum.

These treatments were repeated July 11, 1908, by Mr. H. T. Osborn. At this date, the tree which had been painted with pure Carbolineum was practically dead, and the other 5 that received treatment with Carbolineum very little diluted, were in an unhealthy, bark-bound condition. All other trees were in excellent condition, and the beetles had apparently abandoned the orchard altogether, quitting the checks as well as the treated trees.

In July, 1910, Mr. Whitmarsh whitewashed a block of trees in the Duroy and Yule orchard which were being attacked by bark beetles, using a spraying machine to make the application. October 26, 1910, he entered the following note: "Today I visited the orchards of Mr. Yule and found the orchard which I had sprayed thoroughly in July, with whitewash, to be badly infested with beetles on the two north rows and not quite so badly infested on the third row from the north side; south of this I could find but few beetles. The probable cause of this infestation was due to the stumps of old trees north of the above orchard and only separated from it by a narrow driveway which is literally swarming with beetles, both *P. liminaris* and *E. rugulosus*. This infestation could probably have been avoided partially or altogether, by thoroughly whitewashing in early September before the hibernating brood of *P. liminaris* emerged. They had bored into the bark very extensively by October for hibernating or feeding, an earlier date by two weeks than such wholesale burrowing is usually done."

The history of a number of orchards in the infested neighborhood confirm the results obtained in our experiments, or in some cases the statement can be reversed, and it should be said that our experiments confirmed the results obtained by the orchardists.

In Mr. Scott's notes for 1909, I find the following entries:

July 1. "One block of trees (back of Mrs. S. L. Kinglets) which was badly infested last year, but received treatment, shows scarcely any beetles at all."

July 30. "In looking over the experimental orchard, I find that some of the weaker trees show some beetles attacking them, noticeably on those parts of the tree which are partly dead or dying. On other more healthy parts of the same trees the beetles have made attacks but in most instances are repulsed by the copious exudations of sap. Such attacks usually extend well into the top and smaller limbs of the trees and in several instances the loss of sap has been great enough to so weaken the trees that egg burrows can be completed without the beetles being driven out by the flow of sap.

One tree, on the row receiving only whitewash, is quite badly infested and will die, notwithstanding the treatment given. This tree is situated in a low and wet spot which contributes to lower the vitality of the tree so the beetles can obtain a foothold. Several of the weaker trees which received 12 percent Carbolineum emulsion show attack more or less serious, as do also weak trees treated with Chloro-naptholeum emulsion and with whitewash cement."

"Out of the block treated with 12 percent Carbolineum emulsion, 3 trees died and 2 others were weakened, but are now recovering.

The other trees in this block were not injured at all. On the contrary, the foliage seems to be a darker green and more healthy and luxuriant than it is on some of the other trees, and the fruit is abundant and maturing in good form. Trunks and limbs are smooth and healthy, but are coated a dark brown. This results from a well-mixed emulsion, applied while warm. The emulsion killed the small twigs (more or less tender) on the trunks and near the bases of the larger limbs. Older and more mature wood was not injured. The 3 trees killed by application of the 12 percent Carbolineum emulsion were cut down today and placed in the out-door insectary for beetles to emerge. The main limbs and many of the smaller ones, even to the top of the tree, were full of larvae in all stages, from those just hatched to full grown ones, and some pupae were found. Cutting into some of the burrows, both *E. rugulosus* and *P. liminaris* were found, the former probably being most numerous. The block of trees on the Wolcott place, treated March 1, by Mr. W. H. Wright, with pure Carbolineum are all dead. The trees have the appearance of having been varnished. Cutting into the bark, the liquid seems to have penetrated to the living cells and killed the protoplasm."

In March, 1908, the author was called to visit the orchard of Mrs. T. S. Johnson, near Gypsum, Ohio. A block of this orchard adjacent to the woodpile was suffering severely from an attack of bark beetles, the insects evidently issuing from the wood, which was peach, of one or two year's harvesting. In 1908, the diseased trees were cut back and treated with whitewash or Carbolineum emulsion. The following year, 1909, Mr. L. L. Scott entered the following observations, July 26th:

"In looking over this orchard I find that as a general thing the treated blocks are comparatively free from attack of bark beetles. The stubs cut back and sprayed last fall and spring with 12 percent Carbolineum emulsion are all dead, only one or two showing any green shoots and these are dying. Blocks not cut back but sprayed this spring with 12 percent Carbolineum emulsion seem healthy; they have a dark green foliage and very few beetles can be found on them, except on some limbs partly dead and, even here, they are not numerous. A few places were found where beetles had started to bore into healthy limbs, but they had only eaten through the cortex and then quit. No sap had exuded, so it seems probable that the beetles were repulsed by the odor or by the taste of the Carbolineum in the bark. Blocks of trees cut back and whitewashed are sending out a vigorous growth of new shoots and all seem to be living. No beetles could be found on the whitewashed trees, except where a

limb was dying and was so far gone that it had failed to send out any new growth. Remainder of orchard, which was whitewashed without cutting back, is thrifty and few beetles can be found, except on weak, dying limbs. In general, the treatment seems to have been quite effective."

June 2, 1910, Mr. Whitmarsh entered notes as follows: "Visited Mrs. T. S. Johnson's estate and found the adult beetles of *P. liminaris* working to some extent in a few trees, but was unable to find any of *E. rugulosus*." Oct. 24, 1910, he made observations as follows: "Visited Mrs. T. S. Johnson's and went through the peach orchards with Mr. Adams, who is in charge of them. The beetles were working to some extent, but, on the whole, did not seem to be doing so much damage as they did in the spring and summer. The trees treated with whitewash, and those treated with Carbolineum, and those not treated at all, seem to show very little difference as regards bark beetle work. Of the small number of trees treated with the Carbolineum, as noted above, several had died, but I hardly think that it was due to the Carbolineum as the trees were very weak when treated, and probably would have died regardless of any or no treatment. The healthy trees show no ill effects of the spray."

Mr. Whitmarsh made the following record for the Dailey orchards: "July 7, 1911, I visited the large peach orchards of F. W. Dailey & Son, and found that they had the beetle under control. They have accomplished this by thoroughly applying the following mixture three times per year for the past five or six years: One bushel lime, 40 gallons water, 2 gallons Rex lime-sulfur solution, and a couple of handfuls of salt. Mr. Robert Dailey, with whom I talked, said that the orchard was badly infested five years ago, but at the present time a beetle can hardly be found. He expects this year to make only two applications of whitewash, deeming the third unnecessary with the beetles so nearly exterminated."

Mr. Geo. Mallory reported good results from the use of one pint of pine tar to one barrel of whitewash.

Mr. J. L. King made a trip, May 1, 1912, over the ground on which Mr. Wilson and Mr. Scott worked and reports as follows:

"The orchards of Duroy and Yule were thoroughly examined and only two beetles could be found in an old Salway orchard. From Duroy's to Jacobson's many neglected orchards were observed, but only a very few beetles (*P. liminaris*) found. On a wild cherry at Mrs. Jacobson's, quite a few burrows were located in the deep furrows of the bark. Farther east a few more beetles were found in cherry, but in all cases the numbers were small. The orchards of the Kelley Island Lime Co. were all dead, showing the carvings of

P. liminaris in great numbers. They were too old to sustain beetles or larvae any longer. Many of these had been cleared away and burned. Mrs. Jacobson's orchard, which was whitewashed, pruned and fertilized, was doing nicely and had made a vigorous growth in 1911. Mrs. Jacobson states that this orchard was badly infested with bark beetles in 1908, so much so that it was turned over to Mr. Wilson for experimental use. He whitewashed it, pruned it severely, and fertilized it. This strengthened it to such an extent that the bark beetles were entirely resisted."

The beetles appeared in some numbers in the orchards of Mr. S. R. Gill and also those of Mr. Wm. Miller, but soon disappeared. Proper care, cultivation, fertilization, trimming and spraying, with a judicious use of fire, probably operated strongly against the beetles in these orchards, but these routine measures were supplemented to some extent for at least one or two seasons with some whitewashing, a small quantity of Carbolineum being sometimes added to the whitewash.

These experiments and observations confirm the efficacy of the earlier remedies recommended for these insects. Thus, in the Rural New Yorker, May 19, 1883, W. L. Deveraux writes concerning *P. liminaris*: "By simply deferring pruning until early July we may be sure of finding the whole family at home, including the entire progeny for the next year, or the trimming off of all dead limbs may be done in winter or spring and the brush may be piled up in the orchard and await the planting of the brood chambers before applying the torch. They choose trees having rough bark; but they can enter the smoothest twig or young growth as I have observed them do in experimental tests. Thus, if they are headed off by the presence of tar-lime or soap on the trunks, they will repair to the branches and forks."

Dr. James Fletcher in the 26th Rept. Ent. Soc., Ontario, 1895, makes the following observations: "The Peach Bark Borer (*Phloeotribus liminaris*) which for some years has done so much harm in the peach orchards of the Niagara peninsula, has this year been successfully treated by Mr. C. E. Fisher of Queenstown. Noticing that the perfect beetles became active very early in the spring, he would wash his trees with a strong alkaline wash to which carbolic acid had been added. He made his wash as follows: Five pounds of washing soda, three quarts of soft soap and enough water to make six gallons. Air-slaked lime was then added sufficient to make it of the consistency of thick paint. To all this was added three tablespoonfuls of Paris green and one ounce of carbolic acid. This mixture was applied with a whitewash brush, thoroughly

covering the entire trunk of the tree and a few inches up on the limbs. Mr. Fisher reports that at the end of the season he is quite satisfied with the results of the treatment. It would appear from what I have just said, that two applications of this mixture, the first one being made as soon as the beetle becomes active, sometimes as early as March, and another six weeks later, would provide us with an effective remedy for this little pest which for some years has done considerable harm in our Canadian peach orchards."

PIN HOLE BORERS

There are a considerable number of Scolytid beetles, other than the two species which we have treated at length, that work in the heartwood of trees as well as in the sapwood, most of them having a long list of hosts besides orchard trees. The external openings of their burrows resemble those of the bark beetles previously described, but on the average are smaller and suggest pin holes rather than shot holes. These beetles which penetrate the heartwood are less to be feared than those which have the habit of concentrating in great numbers in the growing bark. However, they are sometimes both numerous in and damaging to fruit and other trees. They may cause discoloration of the wood through which their burrows pass, the "blued" or stained areas exhibited by various timbers, when split, often being caused by them. Again, they may fill what would otherwise be valuable timber, so full of pin holes that it is worthless. Some of the species, instead of living upon wood or bark, derive their sustenance from a fungus which grows along the walls of their burrows, and which they introduce and propagate as carefully as the farmer does his grain. Whether or not the burrows are designedly utilized for fungus pastures, they furnish, especially after being vacated by the beetles, entrance for accidental germs of all sorts of ferments, rots and decay.

It seems that, in some cases, where the food supply is abundant and other conditions are congenial, the beetles, upon reaching maturity, do not go outside their burrows to seek new trees, but start new burrows off the old ones, and thus the work of destruction goes on with an acceleration exactly proportioned to the geometrical rate of increase of the insects. However, the fact that the fungus-feeding species are dependent on the normal development of their fungus pastures naturally limits their multiplication, and at the same time suggests effective remedial measures. The young larvae browse on the tender, newly-formed parts of the fungus, while the adults clip back the older and tougher threads. If, for any reason,

the pasturage is interrupted by a reduction in the number of beetles, or if conditions favor a specially exuberant growth of the fungus, there is great likelihood, according to Mr. H. G. Hubbard, that it will over-run and choke the burrows, at the same time overwhelming and suffocating the occupants. So perilous are the conditions under which these insects must propagate, that it is surmised that only under exceptional circumstances does it happen that more than one generation is produced in the same burrow. This is probably the reason why these little pests have never attracted much attention or become wholesale pests in an orchard. If the burrows are closed, the fungus may either fail, or it may over-master the panic-stricken beetles which cannot escape. Therefore, whitewashing or coating the trunks with thick, soapy preparations, or spraying oil emulsions into the burrows to kill the fungi, may all prove very effective measures. Driving wooden pegs or short wire plugs into the external openings of the burrows or pinholes will accomplish the same end. Or, perhaps, poles stuck in the ground will serve as traps and attract the beetles away from the living trees. Bisulfide of carbon may be injected into the holes and the openings then closed with a plaster of mud, putty or grafting wax. In case of severe attack, the trunks and larger branches might be protected by being wrapped with newspapers or old cloths, but for large scale treatment the orchardist will obviously have to depend largely upon keeping his trees in a healthy condition, as free as possible from mechanical injuries and abrasions, and such an operation as whitewashing.

Weakened and unhealthy trees are the ones apt to be attacked, just as is true in the case of the true bark beetles; so proper orchard hygiene, sufficient cultivation, good and abundant fertilization, and correct spraying will furnish the surest safeguards against attack. Where a very few trees are involved, it may be advisable to cut them down at once and burn, if the attack is serious. In case of specially threatening conditions for a whole orchard or neighborhood, should such ever develop, it would be advisable to add whitewashing or similar treatment to the best orchard hygiene; and, further, it might be worth while to girdle a few forest trees, if these were known to be preferred food plants, so as to weaken them and attract to them all the beetles in the neighborhood; after which, while inhabited by the insects, they could be cut down at the most advantageous date and burned.

Brief accounts of some of these pinhole borers affecting orchard trees follow:

BANDED PIN-HOLE BORER

Monarthrum fasciatum Say.

This little beetle is more of a timber pest than an orchard enemy, but a number of times it has been recorded as injuring apple and peach. Mr. G. C. Davis, in 1895 (Trans. Mich. Hort. Soc.) reported this species and the following one injuring peach, both having been previously recorded on apple. Prof. F. M. Webster also recorded it on peach in August, 1895 from Noble County, O. (Ohio Farmer, Aug. 22, 1895). Mr. R. D. Whitmarsh of this Station, under date of June 2d, 1910, speaking of a visit to the orchard of Mrs. T. S. Johnson, Port Clinton, O., says: "I found two peach trees in the orchard just south of the house very badly infested with beetles and, on examination, I found that the borer causing the destruction of the tree was neither *E. rugulosus* nor *P. liminaris*, but *Monarthrum fasciatum*. Mr. J. L. King, May 8, 1912, reports finding this species working on peach in the same orchard. He says: "The beetle was working in the green wood 5 feet above the ground. The burrow was started through a lenticel opening. A second specimen was taken May 20 in much the same environment as the first." Mr. King also enters the following note: "Oct. 14, 1912: In the branches of a dying cherry tree at Mr. Wright's (Lakeside, O.) I found a number of specimens of *M. fasciatum*. The beetles were in long burrows in the heartwood. I find that there is a slight tendency for these beetles to follow the annual rings in the formation of their burrows. As many as three and four beetles may be found in a single burrow. The work of this species is easily distinguished from that of *P. liminaris* and of *E. rugulosus* by the entrance hole and by the white wood-frass which is found at the mouth of the burrow. No eggs nor brood was found in any of the burrows opened." Mr. E. A. Schwartz noted in 1886 that "The main gallery runs in the solid wood concentric with the bark; while the secondary galleries branch off rectangularly from the main gallery and run upward or downward."* He also reported finding about 20 specimensof the beetle in a single gallery. Mr. H. G. Hubbard states that the egg-laying and feeding habits of this species are exactly the same as those of the next species treated. Besides feeding in apple, peach and cherry, Hopkins† lists it, from various authorities, infesting pine, white oak, black oak, basswood, beech and hemlock. He also gives the following dates for capture of adults: Feb. 20, March 2, April 14, 15, 17, 18, May 18, July 21,

Fig. 8. *Monarthrum fasciatum*, enlarged. After Hubbard, Bur. Ent., U. S. D. A., Bul. 7, New Series.

*Proc. Ento. Soc. of Wash. Vol. 1, P. 44.
†Bulletin 32, W. Va. Agr. Exp. Sta.

Aug. 6, 22, Sept. 3. Mr. Chas. Dury reports it as abundant at Cincinnati and gives the following dates of capture: May 7, July 13, Sept. 8, etc. An examination of these dates and our own records indicates the possibility of an early and a late brood, with great irregularity of development, or a single irregular generation may be the rule. Besides the Ohio localities given, there are some specimens in the Ohio State University collection, labelled Columbus, O., and others Defiance, O. In our collection is a number of specimens sent in by D. W. Morrow, Glenville, O., June 1, 1900, taken from maple; they were eating into the bark and wood.

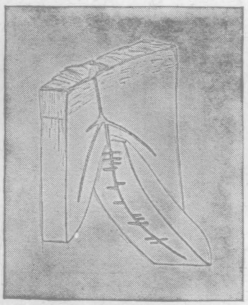


Fig. 9. Gallery of *M. fasciatum*, much reduced in maple. After Hubbard, Bul. No. 7, New Series, Bur. Ent., U. S. D. A.

This has never been a serious orchard pest nor is it ever likely to become such; however, according to our observations and those of others, it may occasionally destroy one or more trees, usually weakened ones.

The beetle is slender and cylindrical in shape and about .10 inch or 2.4mm. long. The antennae are clubbed and in the male are fringed with very long hairs, while in the female, the hairs are few and short, and located on margin of club. The posterior declivity of the wing covers is hairy; and the front part of the wing covers is occupied by a yellow band, the posterior third being black. According to Leconte, it ranges from Lake Superior to Florida.

APPLE PIN-HOLE BORER, OR APPLE STAINER

Monarthrum mali Fitch.

This species is quite similar in habits and general appearance to the preceding species, but is somewhat smaller (2mm. or .08 inch long) and the male is provided with a long, terminal spine and a few hairs at end of club; spine is wanting on club of female. Fitch,* in his original treatment and description of the species, says: "Young thrifty trees, soon after putting forth their leaves in spring, suddenly withering, as though scorched by fire, the bark becoming loosened from the wood, and soon after numerous perforations like pin-holes appearing, penetrating through the bark into the wood, from each of which comes out a very small cylindrical beetle which is smooth, slender, black, sometimes dark chestnut red," etc.

He further states: "I only know this insect from specimens recently sent me from Middlefield, Mass., by Lawrence Smith, Esq., who writes me that he took them July 6, from the trunk of an apple

*Third Report on Insects of N. Y., 1856.

tree ten inches in diameter, which was numerously punctured from the surface of the ground to where the limbs commenced branching off, above which no traces of them were to be found. In another letter, he states that this insect was first noticed in his neighborhood two years ago, when several nursery trees were riddled by them. Nothing was seen of them last year; but they have reappeared the spring of the present year (1857) in greater abundance, and a number of trees have been ruined by them. I find a specimen of this same insect also in a collection sent me several years since from Ohio, by Dr. Robert H. Mack, of Parma." G. C. Davis recorded it on peach in Michigan (Trans. Hort. Soc.) in 1895. Hopkins* gives the following list of host plants; pine, white oak, black oak, jack oak, elm, beech, maple, chestnut, basswood, honey locust, yellow poplar (tulip), buckeye, Morello cherry, cedar and hemlock.

Fig. 10. *Monarthrum mali*, enlarged. After Hubbard, Bul No. 7, N. S. Bur. Ent., U. S. D. A.

Mr. King took a specimen in Mrs. T. S. Johnson's orchard, Port Clinton, May 25, 1912, and in the State University collection are specimens taken at Columbus, O. Mr. Dury has taken it at Cincinnati, but says it is not common there.

The following is a resume of its feeding and breeding habits, extracted from the writings of H. G. Hubbard:† "The young are raised in separate pits or cradles, which they never leave until they reach the adult stage. The galleries, constructed by the female beetles, extend rather deeply into the wood, with their branches mostly in a horizontal plane. The mother beetle deposits her eggs singly in circular pits which she excavates in the gallery in two opposite series, parallel with the grain of the wood. The eggs are loosely packed in the pits with chips and material taken from the fungus bed, which she has previously prepared in the vicinity, and on which the ambrosia has begun to grow. The young larvae, as soon as they hatch, eat the fungus from the chips, and eject the refuse from their cradles. At first they lie curled up in the pit made by the mother, but as they grow larger they deepen their cradles with their own jaws, until, at full growth, they slightly exceed the length of the larva when fully extended. The larvae swallow the wood which they excavate, but do not digest it. It

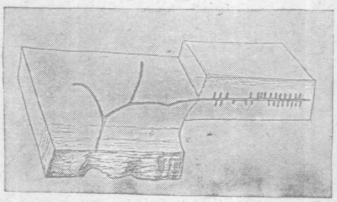


Fig. 11. Gallery of *M. mali*, much reduced. After Hubbard Bul. No. 7, N. S. Bur. Ent., U. S. D. A.

*Bul. 51, W. Va., Agr. Exp. Sta.
†Bul. No. 7, N. S., Bur. Ent. U. S. D. A., P. 9.

passes through the intestines unchanged in cellular texture, but cemented into pellets by the excrement, and is stained a yellowish color. The pellets of excrement are not allowed to accumulate in their cradles, but are frequently ejected by them, and are removed and cast out of the mouth of the boring by the mother beetle. A portion of the excrement is evidently utilized to form the fungus garden bed. The mother beetle is constantly in attendance upon her young during the period of their development, and guards them with jealous care.

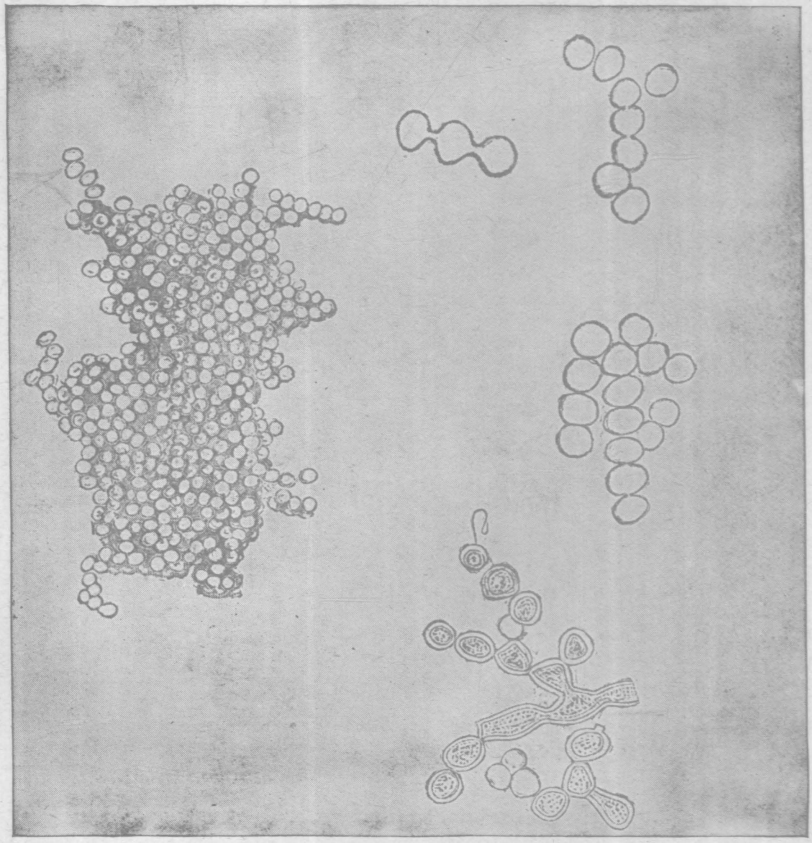


Fig. 12. Ambrosia of *M. mali*, greatly enlarged. After Hubbard. Bul. No. 7, N. S. Bur. Ent., U. S. D. A.

The mouth of each cradle is closed with a plug of the food fungus, and as fast as this is consumed it is renewed with fresh material. The larvae from time to time perforate this plug and clean out their cells, pushing out the pellets of excrement through the opening. The debris is promptly removed by the mother and

the opening again sealed by ambrosia. The young transform to perfect beetles before leaving their cradles and merging into the galleries.

The Ambrosia of *Monathrum* is moniliform and resembles a mass of pearly beads. In its incipient stages, a formative stem is seen which has short joints that become globular conidia and break apart. Short chains of cells, sometimes showing branches, may often be separated from the mass. The base of the fungus mass is stained with a tinge of green, butthe stain in the wood is almost black.

Two species, *M. fasciatum* Say and *M. mali* Fitch are confined to the Atlantic forests, and range in latitude from Lake Superior to Florida. They have identical habits, and feed upon the same fungus. They are commonly associated in the same tree-trunk, not seldom occupying galleries having a common entrance hole. Both species are known to attack wine casks, but they probably breed only in dying trees.

Perhaps the most effective method of preventing injury to wine, cider and vinegar casks is to keep them in dark cellars or darkened rooms as the insects seem to shun such situations. Painting the casks with white paint, with Bordeaux mixture, with whitewash, or with Carbolineum would doubtless assist in repelling the beetles. They probably resort to casks only for the purpose of feeding, as no record has been made of their breeding in such situations. Staves, or wood intended for making barrels or other articles, if infested with these or other timber beetles in whatever stages of development, can be freed from living forms by subjecting the wood to live steam or dry heat for a few hours.

It is improbable that any of these insects would survive 150° Fahr. if continued for 2 or 3 hours.

The trees attacked include oak, hickory beech, maple, aspen, apple and orange, and the list might be extended to include other hardwood timber.

Hopkins gives the following dates for capture of adult beetles: Feb. 20, March 14 to 19, May 4, 8, 30, July 16, 20, 21, 24, 25, 29, 30, Aug. 4, 12, 22, Sept, 3, Dec. 6, Jan. 31. Pupae, eggs and larvae were found July 21. There may be one, two or more broods per year so far as can be inferred from these dates. The beetle ranges from Lake Superior to Florida according to Le Conte.

PEAR BLIGHT BEETLES

Xyleborus dispar Fabricius and *Xyleborus pyri* Peck.

Two other scolytids which may occur in Ohio but which, so far as we have been able to learn, have never been definitely recorded in the state, are *Xyleborus pyri* and *Xyleborus dispar.* The latter

species is an importation from Europe, pitchy brown to black in color, the wing covers inclining to reddish brown. The female is about one-eighth of an inch long, the male considerably smaller. It is known as the Pear Blight Beetle and is injurious to pear, apple, plum, cherry and several kinds of forest trees such as hemlock, beech and oak. It partially girdles young trees, sometimes before they leave the nursery, this causing the death of the upper parts. It tunnels into the trunks of older trees and hollows out the pith and centers of small twigs. The openings into the burrows are small and circular, as is usual with the shot-hole borers. The life cycle in America has not been very thoroughly worked out, but the data gathered indicate the probability of finding the adult beetles packed in the tunnels, end to end, forming a continuous line in the fall and winter months. The eggs for the autumn generation are probably laid in August and September, the larvae being found in the fall and winter, feeding together with the adults on a fungoid growth which lines the tunnels and which is carefully propagated under the intelligent supervision of the insects. The tunnel made by this borer is first toward the center, then a horizontal gallery is made running part way around the trunk or branch, and at right angles to this a large number of galleries are excavated, running up and down the stem. O. Schneider-Orelli* has traced out the life history in Europe and finds that in Switzerland the females migrate to new trees to found new colonies beginning as early as April 19, and may continue such activity throughout a period of two months, according to climatic conditions. Eggs were found May 10, the majority being laid in late May and ceasing wholly with the beginning of June. The number of eggs laid by a single female varied from 6 to 45; these are usually laid in clusters of six, chiefly at the junctions of the tunnel system, seldom being laid in the blind tunnels. The pupal stage

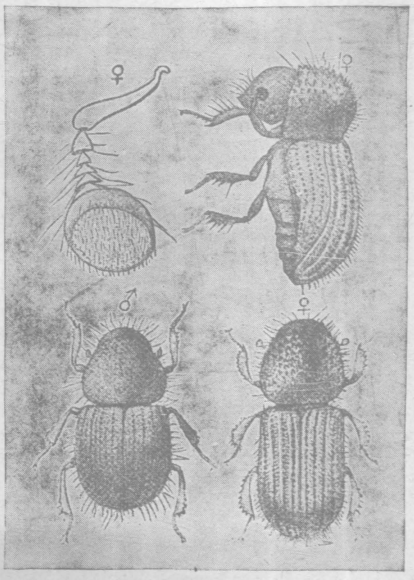


Fig. 13. *Xyleborus dispar:* male and female imagoes, enlarged; antennae of female more enlarged. After Hubbard, Bul. No. 7, N. S. Bur. Ent., U. S. D. A.

*Centralbl. Bakter., Paras. and Insekt., 2 Abt. XXXVIII, No. 1-6, 1913, pp. 25-110.

lasts from 10 to 14 days and the young beetles hibernate in the tunnels. According to these observations there is but one generation per year. A species of *Xyleborus*, probably this species, was received from Hudson, O., May 13, 1912. Badly infested trees should be cut and burned in the fall. Healthy trees, if threatened, should be kept thrifty and whitewashed, or kept covered with a carbolized soap paint to repel the beetles and prevent egg laying.

Xyleborus pyri has been recorded from West Virginia and probably occurs in Ohio. It may possibly be identical with *X. dispar*, and is sometimes found associated with it. It enters the green sapwood and heartwood of logs, stumps, injured living trees, and probably healthy trees as well. In food habits, life history and economy, it may be assumed to closely parallel *X. dispar*. Hopkins records for W. Va., adults May 8, 9; larvae, June 1; eggs, May 8, 9.

TWIG BORERS

All of the species previously treated belong in the family Scolytidae, but two other small beetles of another family, with boring habits, are occasionally encountered and require mention. These belong in the family *Bostrychidae*, or Powder Post Beetles.

APPLE TWIG BORER

Amphicerus bicaudatus Say.

This is cousiderably larger than any other species treated in this bulletin ranging from one-fourth to over one-third of an inch in length. It is dark chestnut brown, or almost black in color, and the thorax is roughened in front with minute elevated points. The male also has two little horns projecting forward on the thorax, one on each side, and a tubercle, or thorn-like projection at the hindermost extremity of each wing cover. The adult beetle bores into small apple twigs in early spring, entering close beside a bud and excavating a channel down the pith which may be several inches long. Both sexes enter twigs in this manner, and sometimes may be found in such burrows in winter as well as during the summer. Twigs of pears and cherries, also grape canes are entered and killed in this manner. During the summer, the beetles generally leave these feeding burrows and deposit their eggs in the dead and dying roots of greenbriar or catbriar (*Smilax*) or in the dead shoots of grape.

Twigs containing the beetles or their burrows should be pruned out and burned and, if the beetles are abundant, destroy all catbriar plants and wild grapes to be found in the neighborhood. Some specimens in the Station collection were sent in from Boggs, O., April 5, 1897. They were said to be abundant at that place and time. Some

more recent reports of damage may have been occasioned by this species, but we have no record, confirmed by specimens, except as above stated.

RED-SHOULDERED SINOXYLON

Sinoxylon basilare Say.

This blackish beetle is closely related to the preceding, but is considerably smaller, being about one-fifth of an inch long and has a large reddish spot at the base of each wing cover. The thorax is furnished with elevated points and short spines in front. The wing covers make such a sudden declivity downward and backward that they appear to be cut off obliquely inward behind, forming a V with the point headward; each side of the V is armed with three teeth. It injures the stems of grapes by boring into them, also the trunks and branches of peach and apple trees. The grub which develops in dead twigs is much wrinkled, yellowish-white and has the anterior segments much swollen and enlarged. The pale-yellowish pupa is formed within the burrow. Infested canes and twigs should be pruned out and burned and the trunks of threatened trees protected as from other small borers. One record from Wooster, Ohio, March 3, 1899, reared in insectary from hickory twigs. We have also received it from Perry, O., July 8, 1910, in peach, it being reported as seriously injurious.